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ON THE EFFECT OF PROLONGED STRESS UPON THE STRENGTH AND ELASTICITY OF PINE TIMBER.

By PROF. R. H. THURSTON.

Presented to the American Association for Advancement of Science, Cincinnati Meeting, August, 1881.

In papers read before the American Society of Civil Engineers at various dates,* the writer has given the results of investigations made to determine the behavior of metals under loads of varying magnitude and under intermitted stresses, and to ascertain in what cases and under what conditions the variation, with period of stress, of the normal line of elastic limits, discovered and announced by him in the year 1873, occurs in practice.

Experiments made by Mr. Herman Haupt,† forty years ago, revealed a fact not even now generally understood and appreciated—that *timber* may be injured by a prolonged stress far within that which leaves the material uninjured when the test is made in the usual way and occupies a few minutes only.

Thus, using pieces $60\times3\times1$ inches ($152{\cdot}4\times7{\cdot}62\times2{\cdot}54$ cm.) set as

* Trans. Am. Soc. C. E., 1873–80; Jour. Franklin Inst., etc., etc.

† Haupt on Bridge Construction.

cantilevers with a breaking moment, due the load, of $P\,l = 48P$ inch-pounds ($122P_m$ kilog.-metres) he obtained for the value of $R = \frac{6\,w\,l}{b\,d^2}$ the following figures:

Kind of Wood.	R.	Time.	Remark.
White pine,	2272	10 minutes.	Injured.
" "	1548	16 days.	"
Hemlock,	2624	5 minutes.	"
"	1620	16 days.	"
Yellow pine,	2848	5 minutes.	"
" "	1800	16 days.	"
Locust,	5504	2 minutes.	Not injured.
"	3600	3½ days.	Injured.
"	2304	16 days.	"
White oak,	4248	15 minutes.	Not injured.
" "	7200	15 minutes.	Injured.
" "	3648	40 hours.	Not injured.
" "	4088	48 hours.	Injured.

All samples tested were considered good selected timber.

An extended series of experiments made intermittently in the mechanical laboratory of the Stevens Institute of Technology, Department of Engineering, during some years past,* had included an examination of this subject and the result has confirmed Haupt's earlier work and has given a tolerably good idea of the effect of prolonged stress in modifying the primitive relation of stress and strain where the wood is good Southern yellow pine.

A selected yellow pine plank was obtained for test, the history of which was known. The stick was cut at Jacksonville, Florida, in October, 1879, was received early in the following year and was piled in the yard, air-seasoning, until taken for test in the spring of 1880. The plank measured $4'' \times 12'' \times 24'$ ($10{\cdot}16 \times 30{\cdot}48 \times 731{\cdot}52$ cm.). When tested, it had been seasoning six months, the latter part of the time indoors.

From the middle of this plank a stick was first cut $3'' \times 3'' \times 24'$ ($7{\cdot}62 \times 7{\cdot}62 \times 731{\cdot}5$ cm.) and from this was cut a set of ten pieces from 40″ to 54″ long (101·6 to 137·2 cm.) and from 1¼″ to 3″ square in cross-section (3·16 to 7·62 cm.) square. These latter pieces were

*Trans. Am. Assoc. for Advancement of Science, 1879–1880; Journal Franklin Inst., Oct., 1879, Sept., 1880.

tested on various conditions, as then reported,* to determine the values of their moduli of elasticity and of rupture.

The moduli of rupture were usually 11,000 to 12,000 for the expression $R = \frac{3}{2} \frac{P\,l}{b\,d^2}$ (in metric measure, 773·3 to 843·6) and the moduli of elasticity ranged from two to two and a quarter millions (in metric measure, $10^6 \times 1406$ to 158175×10^4). In specific gravity the wood ranged from 0·75 to 1·00, usually about 0·85. When kiln-dried to a moderate extent, the density was but little altered, if at all, but the modulus of elasticity rose to two and a half millions (17375×10^5) and the modulus of rupture was increased about 20 per cent.

From the previously unused part of the plank a set of three test pieces was cut about 1 inch (2·54 cm.) square in section and tested on supports 40 inches (101·6 cm.) apart, to determine their breaking loads. The result is shown in detail in the appended table. In these specimens the annual rings were in the cross-section of each piece, indicated by lines making angles of 45° with the edges. These pieces broke at 345, 380 and 410 pounds respectively. The weakest piece broke by splintering, and had it been as sound as the others would probably also have sustained a somewhat heavier load. As will be seen by comparison with the other and with subsequent tests, the deflection of the strongest piece in the set is exceptionally small and the piece probably exceptionally strong and stiff. We may therefore take 375 pounds (170 kilog.), or a trifle over, as a good average for loads breaking pieces of this size.

Nine other pieces were cut and dressed to the same size and were mounted on supports 40″ apart, in a frame arranged for the purpose in the workshop of the Institute, in three sets of three each.

These sets were loaded thus:

1st set,	250 pounds (113·6 kilogs.);	Table 2.
2d set,	300 pounds (136·4 kilogs.);	Table 3.
3d set,	350 pounds (158·1 kilogs.);	Table 4.

Or to about 60, 80 and 95 per cent. of their probable maximum strength, as indicated by ordinary test of the companion lot above described. Their deflections were measured when set, and at intervals subsequently, by means of an accurate micrometer reading to ten-thousandths of an inch.

* Trans. Am. Assoc., 1880; Journal Franklin Inst., 1880.

The whole set of bars, loaded most heavily as above, broke within two days; one bar yielding, as shown in Table 2, at the end of a period included between observations taken at 4½ and 13½ hours from the beginning, the second breaking at some time between 27 and 30½ hours and the third giving way at the end of 43 hours. A load of 87½ per cent., the maximum obtained by usual methods of test, is thus shown to be capable of breaking the piece under the conditions here described, and an apparent "factor of safety" of 1⅛th is evidently not a factor of safety at all when time is given for the piece to yield.

The second set, loaded with 0·75 the maximum momentary weight, all broke, as is shown by Table 3, one at the end of about 3½ days, another after 5 days, and the third at the end of a little more than a month. It is probable that these differences of time are due to differences of strength more than to variations of the effect of time of stress. A "factor of safety" of 1⅓ is evidently not a real factor of safety for wood in such cases as this.

The behavior of the third and last set of test pieces is shown in Table 4. These pieces were loaded with 60 per cent. of the average breaking weight under ordinary test. Left under this load, the deflection, in every instance, slowly and steadily increased from about one inch (2·54 cm.) to some considerably larger amount at the end of the period of investigation. Fortunately, as is indicated by a comparison of these initial deflections with those observed under the same weights when testing the first set, and by their close accordance with each other, these pieces were all good samples of a good quality of yellow pine.

The increase of deflection was almost precisely the same for all for several months, a fact which is of importance, as showing not only the gradual progress and the steadiness of yielding, but also that no accident produced final rupture. Finally, after several months (about 6000 hours; the exact time is uncertain), the piece which had at the beginning shown most pliability broke completely down. The next piece to break was that which was intermediate in stiffness between the two others; it broke at the end of about 9000 hours—precisely one year from the date on which the load was imposed.

The last of the three pieces of this set still carried its load of 60 per cent. of the maximum under ordinary test at the last date, but it was still very slowly but unmistakeably yielding, its deflection having increased nearly 0·4 inch (1·016 cm.) during the preceding five

months. *It finally broke July 31st, 1881, about eleven thousand one hundred hours after it received its load* (15 *months*), which load was, it will be noted, but about 60 per cent. of its estimated—and probably practically correct—original breaking weight.

This very remarkable result fittingly terminated this series of tests of wood subjected to prolonged stress. An inspection of the broken bars gave no indication of reduction of strength by decay; the pieces were perfectly sound and the fractures showed excellent material.

Comparing the ultimate deflections attained by the several sets of bars it is seen that the average under ordinary test was about 1·8 inches (4·6 cm.). Under a load 0·95 that then carried, the rods broke at a deflection of 2·4 inches (6 cm.); loaded to ·80 the maximum, the deflection became, at the end, 3 inches (7·62 cm.) as a maximum, and the ultimate deflection of the most lightly loaded pieces (70 per cent., the maximum load) was something less.

The last set being compared with the first, it is seen that a load of 60 per cent., the maximum given by the usual form of test, is for such pieces unsafe, and that one-half the ultimate deflection under usual methods of test marked a point beyond which loads become certainly unsafe, although it would seem that a slightly smaller load might have been carried indefinitely, or until decay should weaken the timber. A factor of safety of two would possibly have permitted indefinite endurance under static load.

Taking the probable breaking load under unintermitted stress as 50 per cent., that sustained as a maximum under usual tests, and *then* applying a factor of safety of two, we obtain as a safe factor, based on the ordinary test, 4.

The writer would conclude, then, that timber may be placed with the "tin-class" among metals, as exhibiting a depression of the normal series of elastic limits under prolonged stress, and that this effect is so serious in its character and so important in its effects that an extended and complete investigation of the phenomena as exhibited in timber of various sizes, and of all the kinds in use in engineering, or in construction generally, would be of great value, even if not imperatively demanded.

In brief, the conclusions to be drawn from the research here described as having been made during the past fifteen months in the Mechanical Laboratory of the Department of Engineering of the Stevens Institute of Technology are evidently that small sections of

yellow pine timber yield steadily over long periods of time under loads exceeding 60 per cent., the maximum obtained by ordinary tests of their transverse strength, and finally break after a period, which with the lighter loads may exceed a year; that deflections half the maximum reached under test may be unsafe for long periods of time, and that a factor of safety of at least 4 should be used for permanent static loads when the character of the material is known.

The writer would, in the light of what is now known, always use a factor of safety of at least 5 under absolutely static load, and when the uncertainties of ordinary practice as to the exact character of material, and especially where shake and the impact of live load were to be considered, would make the factor not less than 8, and for much of our ordinary work 10.

The above experiments were arranged and supervised by Mr. J. E. Denton, and the observations made and recorded by Mr. A. Riesenberger, to both of whom the writer is under great obligations for intelligent and zealous assistance and co-operation in this as in many other investigations.

Hoboken, N. J., July 31st, 1881.

TABLE 2.

Time test; P = 350 lbs.

A.	B.	C.
$b = 1{\cdot}1$; $d = 1{\cdot}1$	$b = 1{\cdot}12$; $d = 1{\cdot}12$	$b = 1{\cdot}1$; $d = 1{\cdot}1$

Distance between supports 40″.

Load Lbs.	Time load was applied. Hours.	Deflection. Inches.	Time load was applied. Hours.	Deflection. Inches.	Time load was applied. Hours.	Deflection. Inches.
40 (weight of box).						
350	.....	·1565	.....	·1705	.....	·1840
350	.....	1·7350	.....	1·7175	.....	2·0300
			Between			
350	18	2·3385	27		¼	2·3500
			and	Broke	Between	
350	43	Broke	30½		4½ & 13½	Broke

Table 1.

Usual method of test.

A.	B.	C.
$b = 1{\cdot}113$; $d = 1{\cdot}105$	$b = 1{\cdot}107$; $d = 1{\cdot}107$	$b = 1{\cdot}1$; $d = 1{\cdot}1$

Distance between supports 40″.

Load, lbs.	Deflection, inches.	Load, lbs.	Deflection, inches.	Load, lbs.	Deflection, inches.
0	—	0	—	0	—
50	·2127	50	·2035	50	·2188
After 5 min.	·2164	After 5 min.	·2125	After 5 min.	·2231
100	·4339	100	·3935	100	·4528
" 5 "	·4378	" 5 "	·4000	" 5 "	·4623
150	·6575	150	·5805	150	·6833
" 5 "	·6696	" 5 "	·5835	" 5 "	·6950
200	·8984	200	·7640	200	·9298
" 5 "	·9146	" 5 "	·7730	" 5 "	·9468
250	1·1552	250	·9630	250	1·2058
" 5 "	1·2286	" 5 "	·9775	" 5 "	1·2433
300	1·5109	300	1·1805	300	1·5648
" 5 "	1·5931	" 5 "	1·2180	" 5 "	1·6713
" 6 "	1·6029	350	1·4705	" 6 "	1·6883
350	1·9329	" 5 "	1·5381	325	1·8568
380	Broke	" 6 "	1·5700	340	Splintered
....	.....	410	Broke	345	Broke

Table 3.

Time test; P = 300.

A.	B.	C.
$b = 1{\cdot}11$; $d = 1{\cdot}08$	$b = 1{\cdot}1$; $d = 1{\cdot}12$	$b = 1\,1$; $d = 1{\cdot}12$

Distance between supports 40″.

Load. lbs.	Time load was applied. Hours.	Deflection. inches.	Time load was applied. Hours.	Deflection. inches.	Time load was applied. Hours.	Deflection. inches.
40 (weight of box).						
300	.....	·1641	.....	·1470	.....	·1930
300	.....	1·4461	.....	1·1215	.....	1·6725
300	1	1·5980	½	1·1835	1	1·8660
300	3	1·6666	3	1·2370	2	1·8950
300	5	1·7316	4¼	1·2735	18½	2·2450
300	22½	1·9171	5	1·2770	44	2·5450
300	47½	2·1026	21¾	1·4280	50	2·5920
300	54	2·1316	46¾	1·5485	66½	2·7310
300	70½	2·2596	69¾	1·6380	74½	3·0000
300	78½	2·4796	77¾	1·7740	betw'n 79½ & 88½	broke.
300	95½	2·7586	94¾	1·8505	.....	....
300	118½	3·0586	117¾	1·9360	.....	....
300	121	broke.	141¾	1·9610	.....	....
300	....	....	165¾	1·9830	.....	....
300	.....	....	189¾	2·0050	.....	....
300	.....	....	238	2·0280	.....	....
300	.....	....	262	2·0440	.....	....
300	.....	....	286	2·0580	.....	....
300	.....	....	310	2·0630	.....	....
300	.....	....	335	2·0810	.....	....
300	.....	....	359	2·1110	.....	....
300	.....	....	406	2·1310	.....	....
300	.....	....	430	2·2110	.....	....
300	.....	....	454	2·2820	.....	....
300	.....	....	478	2·4570	.....	....
300	.....	....	502	2·5510	.....	....
300	.....	....	526	2·5870	.....	....
300	.....	....	598	2·6435	.....	....
300	.....	....	622	2·6520	.....	....
300	.....	....	646	2·6600	.....	....
300	.....	....	919	broke.	.....	....

Table 4.

Time test; P = 250 *lbs.*

No. 1.	No. 2.	No. 3.
$b = 1{\cdot}08''$; $d = 1{\cdot}1''$	$b = 1{\cdot}08''$; $d = 1{\cdot}1''$	$b = 1{\cdot}1''$; $d = 1{\cdot}1''$

Distance between supports 40″.

Load. lbs.	Time load was applied. Hours.	Deflection. inches.	Time load was applied. Hours.	Deflection. inches.	Time load was applied. Hours.	Deflection. inches.
37 (weight of box).						
250	.....	·1342	.....	·1532	....	·1290
250	.....	1·0317	.....	1·0403	.....	·9821
250	91	1·2927	90	1·3757	89	1·2696
250	161½	1·3967	160½	1·5132	159½	1·3796
250	185½	1·4077	184½	1·5402	183½	1·4076
250	210½	1·4237	209½	1·5592	208½	1·4246
250	233½	1·4372	232½	1·5862	231½	1·4446
250	258½	1·4942	257½	1·6602	256½	1·5196
250	281½	1·5227	280½	1·7042	279½	1·5651
250	305½	1·5377	304½	1·7217	303½	1·5736
250	329½	1·5547	328½	1·7402	327½	1·5856
250	353½	1·5657	352½	1·7492	351½	1·6036
250	402	1·5797	401	1·7662	400	1·6216
250	426	1·5897	425	1·7762	424	1·6286
250	450	1·5957	449	1·7852	448	1·6346
250	474	1·5997	473	1·7872	472	1·6396
250	499	1·6097	498	1·8032	497	1·6506
250	523	1·6257	522	1·8132	521	1·6636
250	570	1·6617	569	1·8632	568	1·6916
250	594	1·7047	593	1·8832	592	1·7336
250	618	1·7417	617	1·9522	616	1·7646
250	642	1·7777	641	1·9982	640	1·8066
250	666	1·8187	665	2·0342	664	1·8456
250	690	1·8347	689	2·0522	688	1·8566
250	762	1·8677	761	2·0852	760	1·8866
250	786	1·8777	785	2·0932	784	1·8946
250	810	1·8827	809	2·1032	808	1·9026
250	1195	1·9832	1194	2·1822	1193	1·9906
250	2107	2·1777	2106	2·3912	2105	2·1696
250	2923	2·2757	2922	2·4917	2921	2·2676
250	6715	2·9297	6066 ±	broke.	6713	2·6416
250	8899 ±	broke.	.....	....	.....	....
250	.....	....	.....	....	11100	broke.

AN EXPERIMENTAL INQUIRY INTO THE RELATIVE ECONOMIC EFFICIENCIES OF A CORLISS CONDENSING AND A CORLISS NON-CONDENSING ENGINE, WORKED BY SATURATED STEAM OF NEARLY THE SAME BOILER PRESSURE IN UNJACKETED CYLINDERS.

By Chief-Engineer ISHERWOOD, U. S. Navy.

An important problem in steam engineering is the determination of the boiler pressure at which the economic efficiency of a non-condensing engine becomes equal to that of a condensing engine using steam of the same boiler pressure; there being included among the factors of the problem the difference in the temperature of the feed-water in the two cases, and the power required to work the air-pump of the condensing engine.

In favor of the condensing engine are the very much less back pressure against the piston than with the non-condensing engine, and the greater measure of expansion with which the steam can be used in consequence of that less back pressure. And in favor of the non-condensing engine are the higher temperature of the feed-water than with the condensing engine, and the saving of the power required to work the air-pump.

Now, as the back pressure in the two cases may be taken as practically constant, say, for good practice, 3·5 pounds per square inch against the piston of the condensing engine, and 16 pounds per square inch against the piston of the non-condensing engine; and, as the temperature of the feed-water in the two cases may also be taken as practically constant, say 100 degrees Fahrenheit for the condensing engine and 200 degrees for the non-condensing, there is evidently a boiler pressure—or rather an initial cylinder pressure—at which the economic efficiencies of the two types of engine become equal.

From the data it would seem that the boiler pressure in question admitted of exact calculation and did not require an experimental determination, and such would be the fact were the steam used in cylinders whose material remained unaffected by heat, but as the cast iron of cylinders is greatly affected by heat, accepting and deliv-

ering it largely and with wonderful rapidity, the question passes from the abstract to the concrete form, becoming purely experimental, like all questions in physics, no confidence being due to any merely mathematical discussion of the case. One of the most important causes of steam condensation in a cylinder being the difference between the extreme temperatures in it during a double stroke of the piston, and these extremes, with constant initial pressure, being greatly affected by the back pressure which lessens them as it increases, this latter factor influences the problem to a far greater extent than its statical value alone. The extent of that influence can only be ascertained by experiment which including the obscure physics of the subject, unknown to calculation but potent on the result, is able to give a true solution when a mere mathematical treatment would lead to excessive error.

As experiments have abundantly proved that no economic gain is to be obtained by using steam with measures of expansion beyond the very moderate ones easily commanded in non-condensing engines worked by steam of not less than 70 pounds boiler pressure per square inch above the atmosphere, the idea may be definitely dismissed that the possibility of carrying expansion in the condensing engine to a greater degree than in the non-condensing one, is an economic advantage.

The higher temperature of the feed-water with the non-condensing engine results from the greater sensible heat of its exhaust steam which is utilized by means of a "heater" in raising the temperature of the feed-water. The sensible heat thus utilizable with either engine is practically controlled by the back pressure against which the steam exhausts; the higher that pressure, therefore, the higher will be the temperature of the feed-water; and as the non-condensing engine exhausts against a much higher pressure than the condensing one, the temperature of its feed-water will be correspondingly higher.

The same boiler furnishing equal weights of steam of the same pressure in equal times, but supplied with feed-water of different temperatures, will have a higher economic vaporization with the hotter feed-water, additional to what is due to the difference of heat to be imparted in the boiler in the two cases, owing to the slower combustion of the fuel. The hotter the feed-water, the less heat is required to be imparted to it in the boiler, so that for equal weights vaporized in equal times, the slower proportionally will be the rate at which the fuel is consumed, whence results that a less quantity of heat being

thrown on the heating surface of the boiler in a given time, the more of it will be absorbed. This gain would appear were the economic results of the experiments to be measured by the weight of fuel consumed per hour per horse-power developed, but it does not appear when they are measured by the number of Fahrenheit units of heat consumed per hour per horse-power.

To work an air-pump requires a power equal to the lifting of the water of condensation and the condensing water a certain height, to the expulsion of the air and uncondensed vapor, and to overcoming the friction of the mechanism, all of which is saved by the non-condensing engine.

Comparable experiments with the two types of engine are rarely found, but being in possession of the details of the trials made in 1878 on a Corliss condensing steam engine in the city of Mulhouse, Alsace, Germany, and published in the last May and June numbers of this journal, and of the still more copious details of the excellently conducted trial made by Mr. John W. Hill of a non-condensing Corliss steam engine, in 1874, for the Fifth Cincinnati Industrial Exposition, I am able to offer an experimental determination of the boiler pressure which in the case of the non-condensing engine gave an economic result equal to that given by the condensing engine operated with nearly the same boiler pressure.

Both engines were land engines, both had precisely the same valves and valve gear, both had horizontal cylinders with the same stroke of piston, both had the same proportion of space in clearance and steam passage at one end of the cylinder to space displacement of the piston per stroke; the only dimension of importance in which they differed was the diameter of the cylinder, which was fifty per centum greater in the condensing engine than in the non-condensing. In both engines saturated steam was used without cushioning or sensible release or lead. Neither was steam-jacketed; the cylinder of the non-condensing engine had no jackets, and although that of the condensing engine had jackets, yet during the experiments with it selected for comparison (Experiments *B* and *C* of the table opposite page 372 of the last May number of this journal) there was no steam in them. Both cylinders were well felted and lagged.

The valves and valve gear of both engines were alike. Each cylinder had two steam valves, one at each end and upon its upper side; and two exhaust valves, one at each end and upon its lower side.

The valves were all horizontal circular slides working with the steam pressure on their backs. They were operated by bell-crank levers keyed to their stems, to which levers rods were articulated connecting them with a wrist-plate oscillating on a journal supported by the side of the cylinder. The wrist-plate received its motion from a rod hooked on its arm at one end and attached at the other to an upright lever at the side of the engine frame, which in turn received its motion from the rod of an ordinary eccentric. The wrist-plate is moved through an arc of considerable extent, and owing to the manner of its connection with the eccentric, has its speed of oscillation maintained after the crank has passed its dead centres; so that approximately the initial opening and final closing of the valves are performed while they are at their greatest speed. The valves when closed have a slow movement, because their connecting rods are then in a position approximately radial to the journal on which the wrist-plate oscillates. The two rods connecting with the exhaust valves have permanent articulation with the levers on their valve stems; but the two rods connecting with the steam valves are detachable from the levers of their valve stems, the detachment being effected by the action of the governor at any point during the stroke of the piston. The steam valves, when detached, being free, are closed quickly by the fall of a weight suspended by a rod from the bell-crank on the valve stem, and working in a dash-pot beneath. This detachment and quick closing of the steam valves enables them to be used also as cut-off or expansion valves, the point of cutting off being variable by the governor. The two rods connecting the wrist-plate with the levers of the steam valves are attached to these levers by a hook on the upper side of the lower branch of what is called a "crab claw" which is jointed to the rod, and the detachment of this hook from the valve lever is effected by a cam-like projection or stop which oscillates on the valve stem bushing and is connected with the governor. The position of this stop being thus variable by the vertical movement of the governor, causes the detachment of the hook earlier or later in the stroke of the piston accordingly, and thus changes the point of cutting off the steam.

All the valve stems extend clear through the backs of the cylindrical valves, for which distance they are made flat, the backs of the valves being slotted to receive them. Thus the valves are not sus-

pended on their stems, which latter only work but do not support them, leaving the valves free to rest directly on their seats and follow down the wear.

The purpose of this valve gear is to open and close the valves with the maximum velocity. To cut off the steam by detaching the steam valves and leaving them free to close with as great velocity as can be given to them by a falling weight, the moment of detachment being variable by the action of an ordinary governor. The economic effect to be obtained being whatever might be due to the lessening of the small rounded corner on the indicator diagram where the cut-off valve closes, formed by the necessarily slow or gradual closing of that valve in any case. And also to the quick opening and closing of the exhaust valve, which allows the minimum back pressure against the piston to be obtained as quickly as possible and held as long as possible. The valve gear was also used to graduate the power, instead of a throttle valve, the graduation being effected with a constant initial cylinder pressure by the shorter or longer cutting off of the steam. And as this valve gear was contrived in the faith that every increase of expansion with which the steam was used, down to nearly the back pressure, increased its economic efficiency, the supposition was that the shorter points of cutting off, following each decrease in the load, caused a material saving of fuel. Further, the use of four valves, two at each end of the cylinder and of the slide type, reduced the space in the steam passages to the minimum, and thereby undoubtedly saved fuel to a corresponding extent; while the straightness and shortness of these passages prevented the lowering of the steam pressure and the raising of the back pressure due to longer and more tortuous passages.

Both the condensing and the non-condensing engines had been put in the best state possible for the trials, which were made with the utmost care and every precaution for exactness by competent and disinterested persons. In both cases indicator diagrams were taken every fifteen minutes from each end of the cylinders, together with a complete set of observations of the other data. The steam pressure, load, point of cutting the steam, speed of piston and all the other conditions were maintained without sensible variation during each experiment. All the instruments and measures used were previously tested. The revolutions of the engine shaft were noted from a counter. The weight of feed-water consumed was accurately measured in tanks and

there was no doubt that all this water was vaporized and that all the steam generated from it entered the cylinders whose pistons and valves had been secured steam tight. In both experiments, the power required to work the engines, *per se*, was calculated from indicator diagrams taken from the unloaded engine with its piston at the same speed as during the experiment.

Had the cylinders in the two cases been of the same diameter, and had their piston speeds been the same, the experiments would have been absolutely comparable. As it was, the non-condensing cylinder had a diameter of $16\frac{1}{16}$ inches, while the diameter of the condensing cylinder was 24 inches, which was in favor of the latter, economically, as regards the loss by cylinder condensation, for that loss, other things equal, is less with greater diameters of cylinder. The speed of the piston of the non-condensing engine was, however, greater than that of the condensing engine in the proportion, roundly, of 60 to 49, which was in favor of the former, economically, as regards the loss by cylinder condensation, for that loss, other things equal, is less with greater speeds of piston. These two differences, therefore, opposing each other as regards the same kind of loss, may be taken to neutralize each other, if not wholly, at least in great part.

In the following table will be found the data and results of these experiments. The quantities have been grouped for facility of reference, and they are so completely described on their respective lines that no further explanation is required. By the indicated horses-power is meant the power calculated for the pressure representing the mean ordinate of the indicator diagram. The net horses-power is the power calculated for what remains of the indicated pressure after deducting the pressure required to work the unloaded engine. The total horses-power is calculated for the sum of the indicated pressure on and the back pressure against the piston. The net horses-power is the only power which is commercially valuable, or applicable to external work.

The temperature of the feed-water given in the table is not the experimental temperature which, in both cases, was considerably less, owing to the water being delivered into tanks for measurement, where it rapidly cooled. The tabular temperature is what it would have had, had it been pumped directly into the boiler without passing through the measuring tanks; and the number of Fahrenheit units of

heat imparted to it, as given in the table, is the number that would have been imparted had it had the tabular temperature.

The quantities in the table are the means of all the indicator diagrams and of all the observations taken. Those for the condensing engine are from the two experiments made on it by a committee for the Industrial Society of Mulhouse, and are the means in function of the duration of each experiment.

Table Containing the Data and Results of Experiments made on Two CORLISS *Steam Engines—one Condensing, the other Non-condensing —to Determine their Economic Efficiency. In both cases Saturated Steam was used without Steam-jacketing, and there was no Cushioning in the Cylinders.*

		Condensing Engine. Mean of two experiments made by a Committee for the Industrial Society of Mulhouse in Alsace, Germany.	Non-condensing Engine. Experiment made by John W. Hill for the Fifth Cincinnati Industrial Exposition.
Dimensions of Cylinder.	Number of cylinders,	1	1
	Diameter of cylinder, in inches,	24	16·0625
	Stroke of piston, in inches,	48	48
	Net area of piston, in square inches,	442·0698	201
	Space displacement of piston, in cubic feet, per stroke,	12·2797	5·5833
	Space in clearance and steam passage at one end of cylinder, in per centum of the space displacement of its piston per stroke,	2·4647	2·9158
	Date of experiment,	8th & 9th April, 1878	3d October, 1874.
	Duration of experiment in consecutive hours,	10·780 and 5·6772	8·0000
Weight of Steam Accounted for by the Indicator.	Pounds of steam present per hour in the cylinder at the point of cutting off the steam, calculated from the pressure there,	.....	1572·0734
	Pounds of steam present per hour in the cylinder at the end of the stroke of its piston, calculated from the pressure there,	.....	1819·6034
	Pounds of steam condensed per hour in the cylinder to furnish the heat transmuted into the total horses-power developed by the expanding steam alone,	....	147·6858
	Sum of the two immediately preceding quantities,	.....	1967 2892

		Condensing Engine. Mean of two experiments made by a Committee for the Industrial Society of Mulhouse in Alsace, Germany.	Non-condensing Engine. Experiment made by John W. Hill for the Fifth Cincinnati Industrial Exposition.
Engine.	Steam pressure in boiler, in pounds per square inch above atmosphere,	66·592	70·477
	Steam pressure in valve chests of cylinder, in pounds per square inch above atmosphere,	63·025	67·500
	Proportion of throttle-valve open,	Wide.	Wide.
	Fraction of stroke of piston completed when the steam was cut off,	0·1050	0·2066
	Number of times the steam was expanded,	7·9033	4·3657
	Pressure in the condenser, in pounds per square inch above zero,	2·0747	.....
	Pressure of the atmosphere, in pounds per square inch above zero,	.....	14·4590
	Number of double strokes made per minute by the piston,	49·19785	60·10833
	Temperature of the feed-water, in degrees Fahrenheit,	100	200
	Number of Fahrenheit units of heat imparted to the feed-water,	1109·3253	1009·5796
	Number of pounds of feed-water pumped into the boiler per hour,	3312·512	2186·870
Steam Pressures in Cylinder Per Indicator.	Steam pressure on piston, in pounds per square inch above zero, at the commencement of its stroke,	70·9000	78·744
	Steam pressure on piston, in pounds per square inch above zero, at the point of cutting off the steam,	.....	71·139
	Steam pressure on piston, in pounds per square inch above zero, at the end of the stroke of the piston,	.....	17·533
	Mean back pressure against the piston, in pounds per square inch above zero, during the stroke of the piston,	3·1124	15·925
	Minimum back pressure against the piston, in pounds per square inch above zero, at commencement of stroke of piston,	.....	15·900
	Mean indicated pressure on piston, in pounds per square inch,	24·1451	25·3775
	Mean net pressure on piston, in pounds per square inch,	21·9810	23·4890
	Mean total pressure on piston, in pounds per square inch,	27·2575	39·8365
	Pressure on piston in pounds per square inch to work unloaded engine,	2·1641	1·8885

		Condensing Engine. Mean of two experiments made by a Committee for the Industrial Society of Mulhouse in Alsace, Germany.	Non-condensing Engine. Experiment made by John W. Hill for the Fifth Cincinnati Industrial Exposition.
Horses-Power.	Indicated horses-power developed by the engine,	127·2987	74·3285
	Net horses-power developed by the engine,	115·8939	68·7973
	Total horses-power developed by the engine,	143·7140	116·6777
	Total horses-power developed by the expanding steam alone,	.....	55·7712
Economic Results.	Number of pounds of feed-water consumed per hour per indicated horse-power,	26·0216	29·4217
	Number of pounds of feed-water consumed per hour per net horse-power,	28·5823	31·7871
	Number of pounds of feed-water consumed per hour per total horse-power,	23·0493	18·7428
	Number of Fahrenheit units of heat consumed per hour per indicated horse-power,	28866.4192	29703·5481
	Number of Fahrenheit units of heat consumed per hour per net horse-power,	31707·0685	32091·6077
	Number of Fahrenheit units of heat consumed per hour per total horse-power,	25569·1716	18922·3485
Cylinder Condensation.	Difference in pounds per hour between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator at the point of cutting off steam,	.....	614·7966
	Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator at the point of cutting off the steam,	.....	28·1131
	Difference in pounds per hour between the weight of water vaporized in the boiler and the weight of steam accounted for by the indicator at the end of the stroke of the piston,	....	219·5808
	Difference in per centum of the weight of water vaporized in the boiler, between that weight and the weight of steam accounted for by the indicator at the end of the stroke of the piston,	....	10·0409

Remarks.

It is greatly to be regretted that, in the original report of the experiment with the condensing engine, the pressures at the point of cutting off the steam and at the end of the stroke of the piston were not given, for then calculations might have been made of its cylinder condensation similar to those made for the non-condensing engine, which would have revealed the cause of the equality of the economic commercial efficiencies of the two engines, notwithstanding the greatly less fraction utilized of the total pressure in the case of the non-condensing engine.

The total horse-power developed in the two cases represents the entire dynamic effect—useful and prejudicial—produced by the steam or fuel expended in equal times, and comparing the cost of the same in Fahrenheit units of heat, there appears that the total horse-power was obtained with the non-condensing engine for an hourly expenditure of 18922·3485 Fahrenheit units, and with the condensing engine for an hourly expenditure of 25569·1716 Fahrenheit units, the two costs comparing as 1·00000 to 1·35127, an enormous difference due to the greater cylinder condensation with the condensing engine combined with the greater number of units of heat required for the production of a pound weight of its steam owing to the less temperature of its feed-water. With the condensing engine there were required 9·8799 per centum more heat to vaporize a pound of feed-water than with the non-condensing engine; and diminishing the above 1·35127, there remains 1·21777 to 1·00000 for the ratio of the economic efficiencies of the non-condensing and condensing engines in function of the total horse-power, the whole of which difference was due to the less cylinder condensation in the non-condensing engine. Now with the non-condensing engine, the final cylinder condensation was 10·0409 per centum of the steam evaporated in the boiler, leaving 89·9591 per centum utilized in the production of power; dividing this latter quantity by the above 1·21777 there results 73·8720 per centum utilized in the condensing engine, which deducted from 100·0000 leaves 26 1280 per centum of the steam evaporated in the boiler condensed in the cylinder of the condensing engine. A condensation in the condensing cylinder of 26·1280 per centum of the steam evaporated in the boiler is then sufficient to account for the difference in the heat cost of the total horse-power in the two cases; and it is known from many experiments that this is about what occurs in an unjacketed

cylinder of the dimensions of the condensing engine cylinder using saturated steam with an expansion of nearly eight times.

By an indirect method, with the data obtained during the series of experiments made on the condensing engine by the committee of experts for the Industrial Society of Mulhouse, the condensation in the cylinder during experiments *B* and *C* hereinbefore referred to, was determined to be 29·6290 per centum of the steam evaporated in the boiler. (See page 435 of the last June number of this journal.)

One of the most important causes of that condensation is the difference of the extreme temperatures of the cylinder during a double stroke of the piston. In the condensing cylinder, the initial steam pressure being 70·9 pounds per square inch above zero, and the minimum back pressure, say, 3 pounds per square inch above the same, the temperatures corresponding to which are 303·62 degrees Fahrenheit and 141·67 degrees, this difference is 161·95 degrees. In the non-condensing cylinder, the initial steam pressure being 78·744 pounds per square inch above zero, and the minimum back pressure 15·9 pounds per square inch above the same, the temperatures corresponding to which are 310·76 degrees Fahrenheit and 215·10 degrees, this difference is only 95·66 degrees. And besides this cause of greater condensation in the condensing cylinder, there was the greater refrigeration produced by the greater measure of expansion with which the steam was used in that cylinder, than in the non-condensing cylinder.

The net horse-power, representing the portion of the total horse-power developed by the engine that was commercially useful, was obtained for the consumption of 31707·0685 Fahrenheit units of heat per hour with the condensing engine, and of 32091·6077 Fahrenheit units with the non-condensing engine; and if a very small allowance be made in favor of the latter for the greater economic vaporization in its boiler per pound of fuel, owing to the slower rate of combustion, the cost of the net horse-power in both cases will be equal; showing that a non-condensing engine with an unjacketed cylinder of the experimental dimensions, using saturated steam of 70½ pounds boiler pressure per square inch above the atmosphere, with an expansion of nearly 4⅜ times, gave the same commercial result—that is to say, the same net power for the same quantity of fuel per hour—as a condensing engine with a two and a quarter times more capacious unjacketed cylinder using saturated steam of 66½ pounds boiler pres-

sure per square inch above the atmosphere with an expansion of nearly 8 times. Hence, under the experimental conditions, no economy would result from the employment of a condenser and air-pump, when the boiler pressure was not less than 70½ pounds per square inch above the atmosphere. If the engine works with a variable load, this must be taken for the lower limit of pressure—not the average pressure—giving equality of economic effect.

Of the total pressure in pounds per square inch above zero with the condensing engine, there were utilized as net pressure $\left(\frac{21{\cdot}9810\times100}{27{\cdot}2575}=\right)$ 80·6420 per centum; and with the non-condensing engine $\left(\frac{23{\cdot}4890\times100}{39{\cdot}8365}=\right)$ 58·9365 per centum; the two comparing as $\left(\frac{80{\cdot}6420}{58{\cdot}9635}=\right)$ 1·36766 to 1·00000 or very nearly the 1·35127 to 1·00000 found as the ratio of the heat cost of the total horse-power in the two cases; so that the less fraction of the total horse-power utilized as net horse-power with the non-condensing engine just balanced the less heat cost of its total horse-power, enabling the net horse-power to be obtained for the same heat cost in both cases.

The correctness of these facts was confirmed some years ago at a large flour-making mill in New York City, which was operated by several non-condensing cylinders of moderate dimensions, unjacketed, and using saturated steam of about 90 pounds boiler pressure per square inch above the atmosphere, with a considerable measure of expansion. The proprietor was persuaded to add a surface condenser and an air-pump, and a variable cut-off, expanding the steam sufficiently more to retain the same mean cylinder pressure with the same boiler pressure, the expectation being that a marked difference in the weight of fuel consumed per hour to grind and dress the same number of bushels of wheat would result; and such indeed was the case, but in the opposite direction to the expectation, the power actually costing so much more fuel that the condenser and air-pump were removed and the original conditions restored.

The foregoing results are true for only the precise experimental conditions, and they will be modified by any of the causes which diminish cylinder condensation, as, for example, steam-jacketing the cylinders, super-heating the steam, employing larger cylinders, etc.,

for there is a greater economic gain possible by them for the condensing than for the non-condensing engine, as the former has the most cylinder condensation to be reduced. Consequently, therefore, just in proportion as the cylinder condensation is lessened by steam-jacketing, steam-superheating and larger cylinders, must the boiler pressure be increased for the non-condensing engine to sustain its equality of economic performance, gaining by the resulting increase of the fraction which the net power is of the total power, what it loses in decrease of relative cylinder condensation. It is probable, however, that with a boiler pressure of from 95 to 100 pounds per square inch above the atmosphere the non-condensing engine would give the net power with fully as much economy of fuel as the condensing engine using the same steam pressure with the measure of expansion found to produce the greatest economy, even with steam-jacketing, steam-superheating and cylinders of the largest dimensions in both cases.

For marine engines, the use of high pressure steam is important, because it lessens proportionally the dimensions of cylinders required for a given power, the dimensions for high powers having now become inconveniently large, and because it allows the removal of the air-pump and appendages. A surface condenser would still be required to furnish the boiler with distilled water, but the quantity of surface could be seriously reduced, the reduction being due not only to the fact that about one-tenth less heat is to be taken out of the exhaust steam, but that owing to the greater difference of temperature on the opposite sides of the condensing surface, a unit of this surface is proportionally more efficient for condensation.

Less than nine-tenths of the refrigerating water would also be used because the difference between its initial and final temperatures in the condenser would be very much greater, so that a portion of the power required for pumping this water with condensing air-pump engines would be saved.

The power expended in working the air-pump and the circulating-pump in marine engines is much greater than in land engines, because of the greater resistance against which they discharge, due to the height of the outboard column of water and to the greater tortuousness of the discharging pipes.

The advantages of the non air-pump engine are, of course, for the cases in which a *uniform* power is employed, as for merchant steamships. For naval steamships which are engined for the development

of high powers during short periods at long intervals, their principal steaming being done with very low powers, the condensing air-pump engine preserves its economic superiority.

DISCUSSION

Of the Papers of C. P. Sandberg on "Rail Specifications and Rail Inspection in Europe," of C. B. Dudley on the "Wearing Capacity of Steel Rails in Relation to their Chemical Composition and Physical Properties," and of A. L. Holley on "Rail Patterns," at the Philadelphia Meeting of the American Institute of Mining Engineers, held at the Franklin Institute, February 17th, 1881.

(Continued from page 118.)

C. E. STAFFORD, Steelton, Pa.: I must confess my high appreciation of Dr. Dudley's conscientious and painstaking work, and of his scientific methods in obtaining the data; but with his method of handling these results and with his conclusions drawn therefrom I cannot agree. The reasons for this difference of opinion I will endeavor to explain.

It is apparent on inspecting his Plates 6 and 7 that the majority of the slower-wearing rails are from the north track, and generally have a longer "time of service," a greater average tonnage per rail, and a smaller average tonnage per year per rail than the faster-wearing, the majority of which are from the south track, and generally have a shorter "time of service," a smaller average tonnage per rail, and a greater average tonnage per year per rail. Have these facts any significance? Have these differences of conditions to which they are subjected any bearing on the relative wearing capacity of these rails? I venture to say they have. I think, after a study of Table I, (an arrangement of lines 17 and 18, Plate 8,) in connection with Plates 6 and 7, we will find that the slower wear of the 32 best rails is only partly due to qualities inherent in the rails themselves, but is principally due to external conditions favorable to slower wear.

In regard to the north and south track, we know that over the south track come the loaded cars from the West, and that over the

north track these cars return, most of them empty. It is evident that this means for the north track a less average tonnage per rail per year; or, in other words, a lower wheel-tonnage. When the load per wheel is less, the resistance and consequently the wear must, necessarily, be less, other things being equal.

"Time of service," also, has an important bearing on the question in hand. It has been only within the last five or six years, as Dr. Dudley has pointed out, that the roadbed of the Pennsylvania Railroad has reached its present admirable condition. Before this time the roadbed was more elastic, more yielding (and probably not uniformly so) than at present. These circumstances might cause a softer rail to be more durable than a harder one, owing to the fact that it would yield more or less to the bending force of the passing load and would thus get a bearing on each cross-tie. The harder rail, on the other hand, being stiffer and more unyielding, would not have this bearing uniformly, and would thus, to a greater or less degree, be subjected to the same conditions as a beam under shock, vibration and a rapidly moving load. Under such conditions, I believe, a harder rail would crush, break and perhaps wear out more easily and quickly than a softer rail. This agrees with Dr. Dudley's statement: "With the improvement in maintenance of way, during the last five or six years, the removal of rails from track from the first two of these causes has quite notably diminished." Under conditions as they now exist on the Pennsylvania Railroad, I believe, the harder rail will give the slower wear. With the ballast comparatively solid and unyielding, as at present, the rail, having a more nearly perfect and uniform bearing, and acting less the part of a beam than that of an anvil must, in my opinion, be a hard one to withstand the pounding of the locomotive and the abrasion due to combined rolling and sliding friction.

Viewed in this light, a hard or soft rail would be respectively preferable as the maintenance of way has become more or less practically perfect. Of the seven rails, in track seven years or less, included in the slower-wearing division, and whose phosphorus units average 40·95, there will be found but one showing, under the same conditions, a slower wear for the softer rail. As these rails were put in track during and after the improvement in maintenance of way they tend to confirm the proposition that with a well-ballasted track

the harder rails give the slower wear. Next under the head of "time of service" comes the consideration of the wheel-tonnage (the average tonnage per rail per year in Table I). This, as pointed out by Mr. Ashbel Welch, has been increased over 60 per cent. within the last five or six years. The speed and the weights of locomotives, cars and trains have also been increased within this period. With the increase of each of these quantities, resistance increases. This increased resistance must be overcome by increased friction between drivers and track, which, other conditions being the same, must result in greater or more rapid wear than formerly. Further, with greater speed and weights the defects in the rolling stock—as flat and improperly coned wheels, worn tires, etc.—must cause greater injury to the rail. It must be borne in mind that the average wheel tonnage of the north track is less than that of the south track during the entire period considered.

It will be noticed, in Table I, that the average tonnage per rail (not the average tonnage per rail per year) of the slower-wearing rails is much greater than that of the faster-wearing. I call attention to this fact because I believe it to be important. We know that the head of a rail when new is more or less rough, and that this roughness wears off rapidly with the first few million tons of service; consequently, if the loss is determined when the tonnage is low, the loss per million tons will not show the actual wearing rate during its future use. Of course, this influence on the wearing rate becomes less and less as the tonnage increases. After wearing off this roughness, it may be that the succeeding few million tons cold-roll or hammer the surface, causing it to more successfully resist subsequent wear. From the history of the road it is evident that those rails having a long time of service possess advantages in favor of slow wear. Not only have they a high tonnage, but they also have had a preparation and wear of the surface while the wheel tonnage was light; the later rails, have, on the other hand, been subjected from the start to a heavier wheel tonnage with the accompanying conditions unfavorable to slow wear. Upon the relative wear on different grades and curves, and combinations of the two, it is unnecessary to dwell.

Having tried to make plain the tendency of each of these conditions, I will now tabulate them:

Conditions Favorable to Slower Wear.	Conditions Unfavorable to Slower Wear.
North track.	South track.
Lighter wheel tonnage.	Heavier wheel tonnage.
Longer time of service.	Shorter time of service.
Greater tonnage.	Smaller tonnage.
Lighter grade.	Heavier grade.
Lower degree curve.	Higher degree curve.

I do not say these conditions will absolutely determine the relative positions of the 64 rails, because we do not know the ratio of the wear of a given rail under a known set of conditions (favorable or unfavorable, or both) to the wear of the same rail under another known set of conditions; also because of conditions not given in the data and because of exceptions named below. But what I have tried to make plain in the preceding remarks is that, in general, the 32 best rails have been in service under conditions, in the main, favorable to slower wear. When this is not the case, the rail, measured by phosphorus units, is hard, and with one exception (rail 915 referred to later), harder than its companion subjected, as far as known, to the same conditions.

To put it more concisely, the slower wear of the 32 best rails is due to external conditions, which, when summed up, are favorable to slower wear, and not to qualities inherent in the rails themselves; except in a few cases, and these when the rails are hard. If this statement is true, then Dr. Dudley's conclusion, that the slower wear of the 32 best rails is due to their being softer than the 32 faster wearing, does not hold.

With the object of learning further what averages of these 64 rails may point out to us, I have arranged them differently, as seen in Table II. We may thus be able to learn whether the indications of the first averages are confirmed or not; or whether the first averages, when studied with the second, may fairly be interpreted to point to, or at least not disprove, conclusions radically differing from those first drawn.

In Table I, which we have just been considering, Dr. Dudley has found that 32 rails of a certain average chemical composition show a much slower wear than 32 rails of a different average chemical composition. The 32 slower-wearing rails averaging softer than the 32 faster-wearing, the conclusion is drawn that this slower wear is due to this fact. Apparently, this inference is true, but as we have

just seen, this slower wear is probably due to other causes. In Table II we have a comparison of rails in the north and south track. This gives us hard and soft rails averaging practically the same chemically as those in Table I, but showing a decided difference in the wear per million tons, comparing the soft and hard of the one with the soft and hard of the other, respectively; also, in the ratio of wear between the soft and hard of each. In Table I this ratio is 1 to 2·03; in Table II, 1 to 1·16. Even this slight difference probably would not have appeared if the north and south rails had been equal in number in both curves and tangents. By consulting Dr. Dudley's Plates 6 and 7 the distribution will be found to be as follows: In tangents, 19 north track rails and 13 south; in curves, only 13 north track rails and 19 south. As it is, the south track rails with a wheel tonnage (average tonnage per rail per year) 62½ per cent. greater, there is a wear only 16 per cent. greater; and this with nearly equal average rail tonnage in both. With these circumstances in mind we may fairly conclude from Table II that, under the same conditions, the harder rails would give the better wear, which indication Table I does not contradict. This conclusion, like the one before, is in favor of the harder rails.

TABLE I.

	North track.	South track.	Total.	Average time of service.	Av. wear per million tons.	Average tonnage per rail.	Average ton per rail, per year.	C.	P.	Si.	Mn.	Phos. units.
All conditions slower wearing.....	22	10	32	9y. — 5½m.	·0506	53,737,156	5,686,104	·334	·077	·060	·491	31·3
All conditions faster wearing.....	10	22	32	6 0	·1028	40,406,260	6,730,871	·390	·106	·047	·647	38·9

TABLE II.

N. track rails...	32	0	32	9	5¾	·0638	46,545,146	4,906,225	·329	·071	·064	·508	31 4
S. track rails...	0	32	32	5	11¾	·0740	47,285,770	7,978,227	·395	·111	·043	·631	38·9

We have considered the conditions furnished by Dr. Dudley favorable and unfavorable to slower wear. That there are other conditions which materially affect the relative wear of rails will readily occur to all.

Among others, in addition to those given, are the following: Whether the speed is the same over all of the rails; whether the rail is subjected to more than ordinary wear by the stopping and starting of, or by the decreasing or the increasing of the speed of trains, as at or near train and watering stations, switches, crossings, sidings, bridges, tunnels, grades, curves, etc.; whether on tangents both sides of track at the same place are at the same level; whether on curve, the rail is taken near entering tangent or elsewhere; whether the elevation of the outer rail in each case corresponds to the average speed of trains at that curve; whether the character and condition of ballast and roadbed is the same for all rails; and other conditions known to those familiar with maintenance of way.

These conditions, more or less local in their character have, it seems to me, been too little considered in the study of "the wearing capacity of steel rails with relation to their chemical composition and physical properties."

With these circumstances in mind, we must agree with Mr. Hunt that "averages are dangerous." In comparing different sets of rails, when, in each set, varying quantities (conditions) too indefinite to be averaged, or not averageable, are associated with others which are definite and can be averaged, and when the maximum and minimum in one set are greater or less respectively than the maximum and minimum of the other, and where a quantity in one rail differs greatly from the other rails in the same set, making the average to differ widely from any quantity of the same kind in that set, can averages give conclusions which can reasonably be accepted as true beyond a doubt? I do not think they can. We have seen that widely different conclusions *can* be drawn from indications given by averages made up from different arrangements of the same rails. Indeed, I believe that conclusions drawn from averages made up from any number of rails, under so many and such different conditions, would be of value only when confirmed by other data.

To properly study the relative wearing capacity of steel rails with reference to their chemical composition and physical properties, we must compare rails subject to the same conditions, as far as is

No. of group.	No. of rail	Time of service. Y.	Time of service. M.	Track.	Grade.	Curve.	Tonnage.	Phos. units.	Loss per yard.	Loss per million tons.	Ratio of Loss. Harder rail = 1.
1	881	11	1	North.	92·4		55,546,811	59·2	3 85	·0693	1 : 1 50
	882	11	1	"				28·1	5·78	·1040	
2	883	10	2	"	95·04		52,174,969	35·7	2·54	·0487	1 : ·83
	884	10	2	"				32·7	2·13	·0408	
3	885	11		"	89·76		55,197,994	33 9	2·74	·0496	1 : 1·63½
	886	11		"				27·9	4·48	·0811	
4	887	11		"	89·76		55,197,994	24·2	2·13	·0386	1 : 1·61
	888	11		"				21·3	3·44	·0623	
5	889	5	11	South.	21·13		44,620,100	33·1	3 54	·0793	1 : ·97
	890	5	11	"				41 7	3·64	·0816	
6	891	7	1	"	40·13		53,687,192	37·7	3·14	·0585	1 : 1 10
	892	7	1	"				33·7	3·46	·0644	
7	894	5	2	"	52 8		38,088,574	45·9	2·93	·0769	1 : 1·03½
	895	5	2	"				45·5	3·03	·0796	1 : 1·04½
	896	5	2	"				40·5	3·04	·0798	
8	913	9	4	North.			45,855,101	33·4	1·01	·0220	1 : 1·31
	914	9	4	"				26·9	1·32	·02s8	
9	915	6	1	"			31,514,889	39·2	0·51	·0162	1 : 0 17½
	923	6	1	"				45 5	2·92	0926	
10	916	6		"			31,127,829	37·5	1 42	·0456	1 : 7 12½
	917	6		"				45·1	0 20	·0064	
11	918	10	6	"			51,720,011	29·9	0·71	·0137	1 : 0·71½
	919	10	6	"				20·3	0 51	·0098	
12	921	5	4	"			27,622,230	37 9	3·05	·1104	1 : 1·50
	922	5	4	"				44·7	2·03	·0735	
13	924	4	1	South.			36,349,989	44·2	1·52	·0418	1 : 1·14
	925	4	1	"				43 8	1 73	·0476	
14	926	9	3	"			76,409,123	30·2	1 53	·0200	1 : 1·13
	927	9	3	"				28·1	1·73	·0226	
15	897	11	2	North (high side).	21·12	5°	52,370,617	33·2	7·31	·1396	1 : 96
	898	11	2					28.1	6·99	·1335	
16	899	11	2	North (low side).	21·12	5°	52,370,617	22·3	2 24	·0428	1 : ·92
	900	11	2					32·2	2·44	·0466	

practical, and which only vary in their chemical composition and physical properties. I have attempted to do this in the foregoing table, made up from Dr. Dudley's level and grade tangents and grade curves. The members of each group have been in the same track the same time, are from the same locality, and have the same grade and curvature (if any); or, in other words, have been subjected to the same conditions, as far as known. It will be noticed that Nos. 893, 920 and 928 of the level and grade tangents have been omitted, and also all of level and grade curves excepting Nos. 897, 898, 899 and 900, because of the impossibility of grouping them in the

same manner, no two having the chemical composition and physical properties as the only variables. Phosphorus units have been taken to show the relative hardness.

Of these 16 groups, 10 decidedly indicate slower wear for the harder rail.

Of the remaining 6 groups, three (groups 2, 9 and 15) come well within the limits of error (·25 pound per yard) inherent in the calculation of the data as pointed out by Dr. Dudley; they cannot, therefore, be considered as exceptions. Groups 2 and 15 are but little outside of the limits of error. Rail 923 of group 9 is obviously abnormal. This is probably due to its being overheated, which the chemical analysis shows might easily be the case, and which the physical tests and its low specific gravity tend to confirm. We may say, then, that 13 of these 16 groups fairly indicate, if they do not definitely point out that, under the same conditions, the harder rail gives the slower wear.

Of course, these comparisons are too few to enable us to arrive at positive conclusions; but indications thus obtained are, I believe, far more valuable and trustworthy than those that averages would give us, made up from any number of rails under many different conditions.

Finally, it seems to me that the conclusions arrived at earlier in my remarks, together with and confirmed by the last, show strong evidence that, under the same conditions, the harder rail will give the slower wear.

O. CHANUTE, New York City: We are very much obliged, I am sure, to Mr. Sandberg for his paper upon "Rail Specifications and Rail Inspection in Europe." We have in the United States hitherto been inspecting rails somewhat haphazard, and we are glad to get the results of Mr. Sandberg's long experience.

We recognize that he was among the first, if not the very first to apply more rational and scientific rules to the designing of iron rails, and, more recently, to adapt these rules to the designing of steel rails, to conform to the capabilities and requirements of this new material. Although we have generally adopted, in this country, sections for steel rails which many of our railway men think even better than those of Mr. Sandberg, he is, nevertheless, the leader in whose footsteps we have followed ever since it has been established

that the fish-joint was the best method of fastening the rails together at the ends.

We have not, however, yet been able to formulate or to adopt any well-established relation between the height and weight of the rail and the weight and speed of the engines, such as he indicates in his Table No. I. For instance, the New York Central rail is $4\frac{1}{2}$ inches deep, and weighs 65 pounds per yard, while its locomotives are of 37 tons maximum weight. The Erie rail is $4\frac{5}{16}$ inches deep, with 63 pounds weight per yard, and the Pennsylvania rail is $4\frac{1}{2}$ inches deep, with 67 pounds weight per yard, while the maximum weight of locomotives upon both these latter lines is 50 tons. Now, which is right? I am inclined to believe that the Pennsylvania Railroad follows the better practice, not because the other rails are too light for the engines, but because inasmuch as steel rails wear out by abrasion, and not by lamination, the Pennsylvania rail promises to be serviceable until about 12 pounds of metal per yard are worn off from the head, while the Erie rail will probably have to be removed from the track when some $8\frac{1}{2}$ pounds are worn off.

Timber is still so cheap with us that we have not hitherto concerned ourselves very greatly about the strength of our rails considered as beams. If after having adopted a rail section, say between 50 and 60 pounds, we have found it a little too limber under increasing weight of locomotives, we have simply put the ties nearer together, and we have thus arrived at the general practice of spacing them about two feet between centres, while I notice that Mr. Sandberg's calculations of required stiffness are based upon having the supports 3 feet apart.

We are careful, however, to limit the weight upon our driving-wheels to a maximum of 12,000 pounds (excepting a few experimental locomotives), and when our gradients and trains require more adhesion than can be obtained from the standard "American" engine, we think it better to adopt the "Mogul" type, with 6 drivers, or the "Consolidation," with 8 drivers; the latter having generally an average of but 11,000 pounds per driving-wheel, and being no harder on the rail than other classes of locomotives.

Believing that much of the wear of rails results from undue pressures, I have made some experiments to determine the area of the surfaces in contact between wheels and rails. These were obtained by jacking up a wheel, and introducing between it and the rail a piece

of thin tissue-paper, underlaid with a slip of black manifold copying-paper. Upon lowering the wheel, it generally crushes a hole in the paper, and gives a fair impression of the surfaces in contact. If the wheel and rail were inelastic, this contact would be a mere line, but as they both yield, it becomes a surface which varies with the weight on the wheel and with its condition.

I found that with 11,000 to 12,000 pounds weight upon a locomotive driving-wheel of about 5 feet diameter the pressures were generally 35,000 to 40,000 pounds to the square inch, although they occasionally ran up much beyond this, but that with 14,000 pounds on a driver the pressures became from 50,000 to 80,000 pounds to the inch, or beyond the elastic limit even of steel.

I also found that under empty freight cars, with say 2400 pounds on a 33-inch wheel, the pressures were generally 20,000 to 30,000 pounds per square inch; that with the car loaded with 11 tons, increasing the weight to say 5150 pounds per wheel, these pressures became about 35,000 pounds to the inch, while if the car was loaded with 20 tons, thus giving 7400 pounds per wheel, the pressures increased to 50,000 or 60,000 pounds to the square inch.

As we increase the weight upon our cars, therefore—and I believe this to be the correct and inevitable practice—we must be prepared to find our steel rails wear out faster than they hitherto have done. We may, perhaps, reduce the pressure by increasing the diameter of car-wheels, but my own judgment is that we should endeavor to limit the weight on locomotive drivers of 5 feet diameter to 12,000 pounds, and on 33-inch car-wheels to about 7000 pounds, so as not to bring crushing strains upon our rails and wheels.

I notice that Mr. Sandberg is disposed to think that our adoption of 30 feet as a normal rail length is an extreme limit. I believe, however, that our mills have found no difficulty in working up to this, and that we get only about 3 per cent. of shorter rails under the provision that not more than 10 per cent. may be delivered under 30 feet, down to 25 feet. The difficulties which he mentions as connected with ocean transportation of 30-feet rails need not concern us much at the present time. I believe that the iron rail mills of this country have the capacity for turning out about 1,000,000 of tons a year, if so many tons of iron rails were called for, and that the steel mills have a present capacity of about 1,500,000 tons, and a prospective capacity, by the end of this year, of some 1,750,000 tons of steel rails per annum.

Now this would furnish us enough rails, if fully employed, to lay or to relay 25,000 to 27,000 miles of track a year. We now have 93,000 miles of railway, of which about 60,000 miles are ten years old and over. Allowing for the postponement of renewals in past years, double tracks, etc., I estimate that these railways will require some 800,000 to 900,000 tons of rails per annum for the next four or five years, to relay their tracks. We are also building some 7000 miles of new railway a year, a rate of progress, however, which I believe we cannot maintain without great risk of running into unprofitable investments, and bringing about a fresh collapse; but even if we do build 7000 miles a year, the aggregate demands for rails in the United States would not exceed 1,500,000 or 1,600,000 tons a year, or a little less than the estimated capacity of the steel works alone for 1882.

We are not likely, therefore, to import many rails from Europe, except occasionally on an emergency, and as a reminder to our manufacturers that there are other railmakers in the world; but if we do, let us not ask the foreign mills to grind off the ends of the rails, to make them exactly of even length, a foreign practice which Mr. Sandberg so justly warns us against. Neither shall we ask them to notch steel rails, except in rare instances, as most of our roads have now adopted, or are adopting, angle fish-plates, to which the notching is transferred, thus preventing creeping through the shearing resistance of the bolts; but we shall undoubtedly require them to drill all holes for the latter, and we find that a round hole, one inch in diameter, with a $\frac{7}{8}$ inch bolt, allows sufficient play to provide for contraction and expansion.

I made some experiments upon rail joints some years ago, which indicated rather better results than those given in Mr. Sandberg's Table No. I, Appendix II. I found that the Erie standard steel rail of 63 pounds weight per yard, upon solid bearings two feet apart in the clear, required the application of a weight of 60 tons on the head in the centre between the bearings to break it; that the old joint, composed of two flat plates, broke with 20 tons similarly applied; that the composite joint, consisting of one flat plate and one angle plate, broke with a weight of 25 tons, while the Erie standard joint, of two angle-plates, 24 inches long, required 34 tons to break it. The flat-plate fishing was, therefore, 33 per cent., the composite joint 41 per cent., and the standard angle-joint 57 per cent., as strong as the

solid rail, and the angle-plate fish showed such marked superiority that our adoption of it was fully confirmed.

But we are especially obliged to Mr. Sandberg for the details and blank forms which he gives us of his methods of inspection. I wish particularly to call your attention to the blank for the inspection book, Appendix IV, and to the form for reports, Appendix V. I think it would be well for us to adopt them for the use of our own inspectors in this country.

I do not, however, quite understand that clause in his specification for *steel* rails (page 30), which, under the head of "Tests," provides that: "2d, The rails must carry, in the same position, a load of -- tons without breaking; after this the flange of the rail will be cut, and the rail broken. The fracture must show perfect welding, especially in the head." I thought it was a peculiarity of steel rails, that they were made from a single piece or ingot, and I am puzzled to imagine how the foreign makers contrive to get welds into them.

You will notice that nearly all my remarks refer to steel rails. I ought to have said so before, but the fact is, that when we now talk or think of rails, it is almost always of steel rails, for the days of iron rails are numbered. Already we see, when we examine one of these diagrams of prices of iron and steel rails, which look so much like the profile of a railway preliminary survey through a mountainous country, that the iron rails average only $5 or at most $10 a ton cheaper than steel rails; and the time cannot be far distant when steel rails will be produced as cheaply as iron. Indeed, I do not believe that any of our roads are now so poor as to be able to afford to buy iron rails, except, as I said before, upon an emergency.

The thanks and support of all railway men are therefore due to Dr. Dudley for his resolute attempt to ascertain the best composition and characteristics for steel rails. He may not as yet have gathered all the necessary data; his present conclusions may have to be corrected with reference to further facts; but I know that he is rendering valuable service, and I believe that he is on the right track.

I quite agree with the remark made by Mr. William Sellers, that the consumer should not undertake to prescribe to the manufacturer how he is to make his rails, nor what materials he is to employ, but should leave him free to select the surest and cheapest way of making a good article. The consumer is interested in the results only; but as

the desired result in this case is that the rail shall wear as long as possible, and as steel rails wear out so slowly that we cannot know for many years which make of them is going to give the very best satisfaction; and while the economical results are so important, I believe that it is our duty to endeavor to ascertain the characteristics of the best rails, to assist the manufacturer to repeat his successes, and to avoid his failures, by giving him whatever data we can gather as to the rails in our tracks.

This, as I understand, is what Dr. Dudley has undertaken to do, by ascertaining the chemical composition and physical characteristics of the rails which have best or worst worn on the Pennsylvania Railroad. While I will presently mention some considerations why his experiments may need to be revised, I yet recognize that he has done and is doing a great public service.

I must say, however, that the chemical composition which he recommends does not strike me as a particularly soft steel. From the criticism which he has received here, I doubt whether Dr. Dudley himself now thinks that he has as soft a thing as he at first imagined. He advises that the phosphorus should not exceed 0·10 of one per cent., the silicon not above 0·04, and that the carbon should aim at 0·30, and the manganese at 0·35 of 1 per cent.

Now the Erie specification of 1876, adopted after consultation with Mr. Holley, reads: "Not less than $\frac{30}{100}$ths nor more than $\frac{45}{100}$ths of 1 per cent. of carbon; not more than $\frac{10}{100}$ths of 1 per cent. of phosphorus, and not more than $\frac{16}{100}$ths of 1 per cent. of phosphorus and silicon taken together. It may contain manganese, but shall be substantially free from other impurities."

In view of the fact that this was the state of the art about the time Dr. Dudley began his labors, and that really *soft* steel, that which we use for our boiler plates, only contains 0·08 to 0·15 of 1 per cent. of carbon, the term of "soft steel," which is much dwelt upon by the author, is rather a misnomer. What he is engaged upon is the ascertaining what are the exact chemical compositions which give absolutely the best rails, and how these shall be distinguished by physical tests. To accomplish this satisfactorily, he will have to gather a good many more data.

I think exception may be taken to the method by which Dr. Dudley has undertaken to ascertain the loss of weight sustained by each rail. Having taken up the whole rail, presumably about 30 feet long,

he has cut out a slice from it, somewhere, one-half an inch thick, and from this slice he has, by weighing and measuring, ascertained the loss of weight. Any one who will caliper a worn rail throughout its whole length, and thus ascertain how much greater is the wear in some spots than in others (differing $\frac{1}{16}$th of an inch in sections 2 inches apart in many cases), will have serious doubts whether Dr. Dudley has in each case hit upon the particular half inch which is a fair representation of that wear.

It seems also difficult to accept the inference to which this method of procedure leads him, when he says that "rails rolled at the same mill, at the same time, and with the same thickness of web, and same shape of foot, differed from each other in the original weight (*as computed*) from $1\frac{1}{2}$ to 3 pounds per yard." Such is not our experience with Erie rails. We find that when the rolls are freshly turned up, the rails run about $62\frac{3}{4}$ pounds per yard, and that this weight is gradually increased, as the rolls wear, to about $63\frac{1}{4}$ pounds per yard; each invoice of say 1000 tons (the shipments are generally of about this amount) averaging as near as may be the 63 pounds per yard represented by the standard template. Here, therefore, we have a variation of only $\frac{1}{2}$ pound per yard, which is the limit assigned by our specification, and, as I said before, it seems hard to believe that on the Pennsylvania Railroad it could have been so much as $1\frac{1}{2}$ to 3 pounds per yard.

I scarcely need to point out that if errors have thus crept into Dr. Dudley's estimates of the loss of weight sustained by each rail, his reasoning and conclusions will be affected throughout. I recognize the difficulty of getting at the wear of a rail the exact original weight of which is not known, but I believe Dr. Dudley will yet find better methods than that of computing it from a half-inch slice. Perhaps more satisfactory results may be reached by a careful calipering of the stem, head and foot of the rail, and ascertaining its density, from which to deduce its original weight, deducting therefrom, to ascertain the wear, the actual weight of the worn rail. In fact, as he finally resorted to the method of averages, Dr. Dudley would have reached nearly the same result by assuming that the rails originally averaged of standard weight, and weighing together each group of eight rails, upon which he bases his deductions of wear.

I may also say a word as to the comparisons of wear upon the

upper and lower sides of curves. These would have been more satisfactory if we had been told the differences, if any, which exist between the elevation of the outer rail on these various curves; also the speeds at which trains generally run over them. The elevation of the outer rail being intended to overcome the centrifugal force, and this, of course, varying with the speed of the train, it is quite practicable for the track foreman to throw the wear upon the inner or the outer rail, by changing the elevation, or, in a less degree, for the locomotive engineer to do the same thing, by running faster or slower than the speed for which the curve is elevated. I hope, however, that Dr. Dudley will check over and continue his investigation. It is not improbable that the result will be still further to confirm his theory.

The railroad men of the whole country, who are specially interested in reaching sound conclusions on this subject, can materially assist in gathering additional data, by taking care to preserve rails which have worn exceptionally well or ill in their tracks, and sending them, with a statement of the particulars of each case, either to Dr. Dudley, if he will consent to test them, or to some of the Bessemer works from which they obtain their steel. All of these have competent chemists; they are vitally interested in maintaining a reputation for making good steel rails, and they would doubtless be glad to make arrangements to analyze and test any specimen rail which might be sent to them, in order to ascertain the causes of its excellence or deficiencies.

In listening to Dr. Holley's paper upon Rail Sections, I was reminded of De Quincey's ideal murderer, who, beginning with a murder, which he thought little of at the time, had gradually fallen to robbing, drinking and Sabbath-breaking, and so on, down to incivility and procrastination. For, having adopted some years ago a rail pattern which I have never recommended to other roads, nor claimed credit for, I now unexpectedly find from Dr. Holley's paper that 62 per cent. of modern rail sections are fashioned after that pattern, that the considerations which guided me are thought worth enumerating, and that it furnishes a good text from which to preach a sermon to railroad men. I hope, however, to satisfy you that I am not entitled to as much notice as Dr. Holley has been pleased to give me.

As Mr. Welch has told you, we were both in 1874 members of a

committee of the American Society of Civil Engineers to investigate the best form of rail sections. He then called my attention to the success of the thin flange and stem of his pattern of 1866, and I adopted them for the Erie Railway, which was then much in need of a standard steel rail section. The beveled head was furnished, ready made, by the sections of old rails which I examined, and was confirmed by the templates of worn wheels, twenty or thirty in number, which I obtained from locomotives and cars. I simply gathered the data, and was guided by them, as any one would have been in my place, and as in fact others had been, for I am informed that Mr. Sayre, of the Lehigh Valley Railroad, and Mr. Fritz, of the Bethlehem Steel Works, had designed and rolled a similar rail as early as 1870.

The Erie rail was originally designed to weigh sixty pounds per yard, this being the limit at that time imposed by the managers of the road. It took some months to get the pattern accepted, some of the rolling-mill managers declaring that it could not be rolled without producing a large percentage of imperfect rails. Mr. L. S. Bent, however, the superintendent of the Pennsylvania Steel Company's Works, thought differently and determined to try it. He found that the percentage of imperfect rails was actually less than with other patterns then in use, and he designed and introduced a number of steel rail sections on the same principle, which have become standards.

Some three or four thousand tons were rolled and laid of the original Erie sixty-pound pattern, and they have stood very well, but Dr. Holley having suggested that the thinness of the foot, in proportion to the head, might cause dangerous internal strains in cooling, and thus make the rail brittle and dangerous, a thickness of one-sixteenth of an inch was added to the foot, increasing the weight to sixty-three pounds per yard, and this has been the Erie standard section ever since. As I said before, in my opinion the Pennsylvania Railroad section of sixty-seven pounds per yard is better, as likely to wear about 50 per cent. longer.

Up to a certain point, there is an advantage in diversity of railroad practice. So long as the best device for a particular purpose is not ascertained, there is a necessity for experimenting, and the resulting variety of design. When, however, the best pattern is approximately agreed upon, the effort should be towards uniformity. This point seems now to have been reached about steel rail sections, although I

had no idea this was the fact, and I hope the railroads will take advantage of the economy which Dr. Holley has shown us to result from the adoption of uniform standards.

He has called our attention to the importance of uniformity in fishing, and especially in spacing the bolt-holes, but he has not told us which he considers the best practice. I venture to present a drawing of the Erie standard joint. (See accompanying plate.) There is nothing novel about it, but the points which we think meritorious are the following:

1st. The holes in the rails are placed as far from the end as we deemed practicable. The centre of the first hole is pitched an even 4 inches from the end of the rail, and the second hole is 6 inches beyond this, or 10 inches from the end.

2d. These holes are drilled in all cases, are 1 inch in diameter, and as near the neutral axis of the rail as we could get.

3d. The fishing is done with angle plates, which we find about 70 per cent. stronger than flat plates. The notching, which is in the fish-plate and not in the rail, is spaced $3\frac{1}{2}$ inches from one end, and 5 inches from the other, so that when the plate, which is reversible, is applied to both sides of the rail, the notches are staggered sufficiently to avoid splitting the ties with the spikes.

4th. The allowance for expansion is made in the fish-plate, the two centre holes being spaced $8\frac{9}{32}$ inches apart. As the next holes are, of course, 6 inches beyond the centre holes, and the plate is designed to be 24 inches long, it will be noticed that if the man at the shears cuts it off at the right length, and the man at the punch centres it exactly, the distance from the centre of the end holes to the end of the plate will be precisely $1\frac{55}{64}$ inches. I hope that Dr. Holley, who says he was appalled at the thought that the mind of man can hit perfection in spacing fish-plate holes within the 64th of an inch will see from this brief exposition of the process that it is more easy to accomplish than he supposed.

5th. The holes in the fish-plate are made oval to allow for expansion and contraction. The bolt, which is $\frac{3}{4}$ of an inch in diameter, is upset under the head to fill this oval hole, and thus prevent turning. It is provided with a hexagonal nut, under which we generally place a thin washer of wrought iron. We have very little trouble from nuts getting loose, so little indeed that, while we have experimented

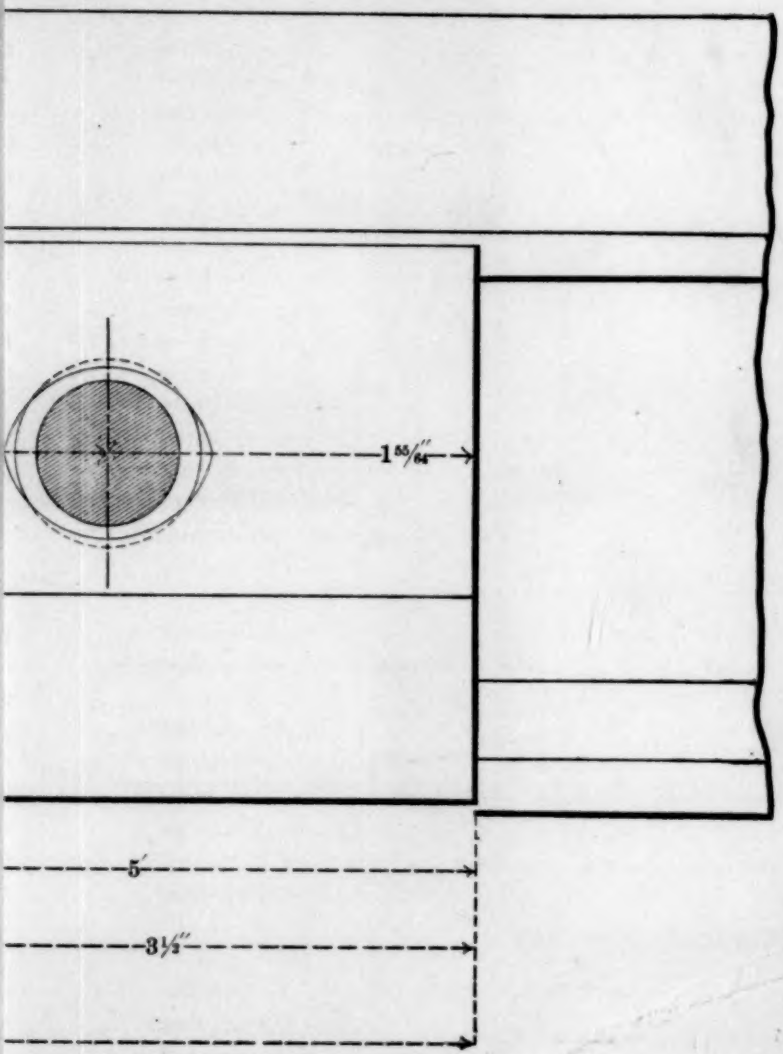
with a number of lock-nuts, we have not deemed it necessary to adopt any of them.

But I fear I am becoming wearisome by my discussion of these details, which would be more appropriate before a special committee on this subject, such as that appointed in 1874 by the Society of Civil Engineers. The main point before you is that so well made by Dr. Holley, of the importance and economy of uniformity in rail sections and fastenings. Of that we have had some experience. We had on the Erie railway, when the new steel section was adopted, 12 patterns of steel rails, 29 patterns of iron rails, and 96 different styles of fastenings. These caused no end of annoyance, delays and expense, in matching or mismatching them, taking up and changing about long strings of rails, and in the large stocks which it was necessary to keep for repairs. This has all been done away with by the adoption of a single pattern of rail and of fastening, and the resulting economy fully confirms all that Dr. Holley has said. He has shown us that the railroads of this country can save several millions a year by adopting uniform rail sections, and as, unfortunately for him, he cannot patent his idea, it only remains for the railroads to adopt it, and to thank him for his paper.

DR. C. B. DUDLEY, Altoona, Pa.: In rising to close this interesting discussion I want, in the first place, to thank every one who has contributed to it for his full and open criticism. The work which has been done on steel rails, and which has been discussed here during these two days, was not done to establish any pet theories, nor to make out that any person was great or any person small, but with a sincere desire to get at what is the truth in regard to the wearing capacity of steel rails. There are enormous commercial considerations involved in this question, and, as I look at the matter, the more honest criticism and fair discussion there is, the more likely it is that the truth will appear.

And first I would like to say that it seems to me very little has been said here upon the main conclusion of the paper, namely, that the softer rails give the better wear. All sorts of side issues have been discussed; but this point, which is really the principal one at issue, has been largely ignored, and I cannot but feel that it still remains unshaken.

With regard to chemists and chemical work, there has been consid-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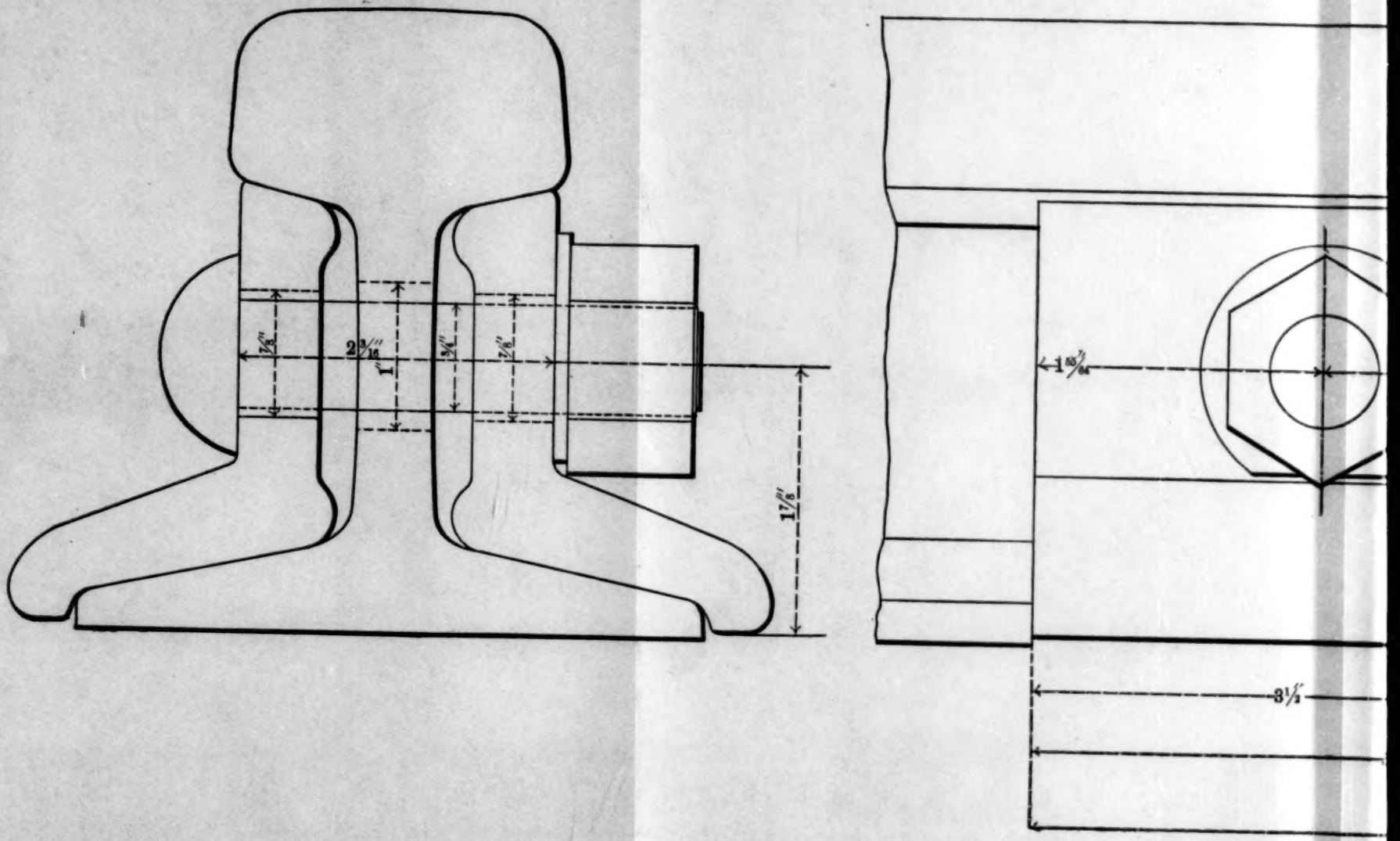
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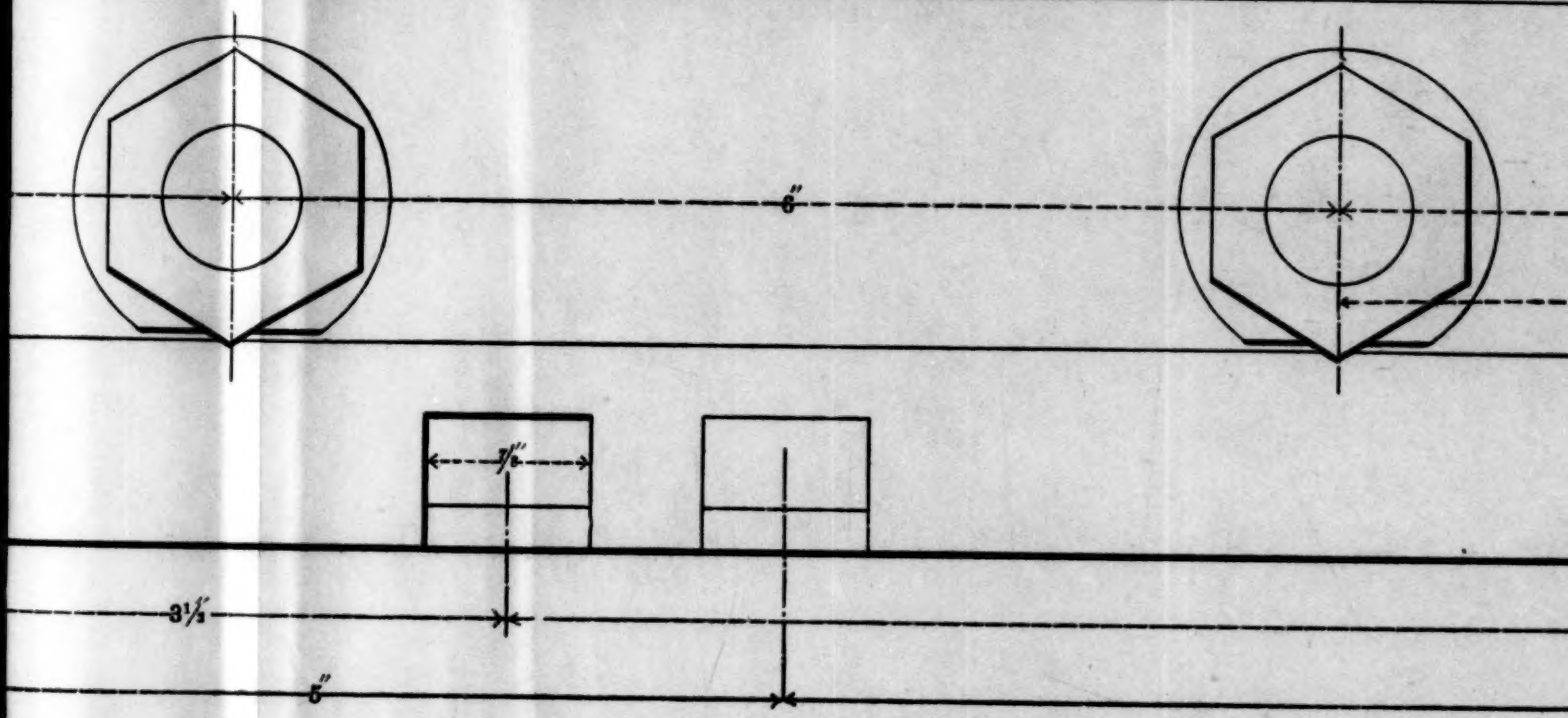
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NDARD RAIL JOINT, — N.V.L.E.& W.R.R.

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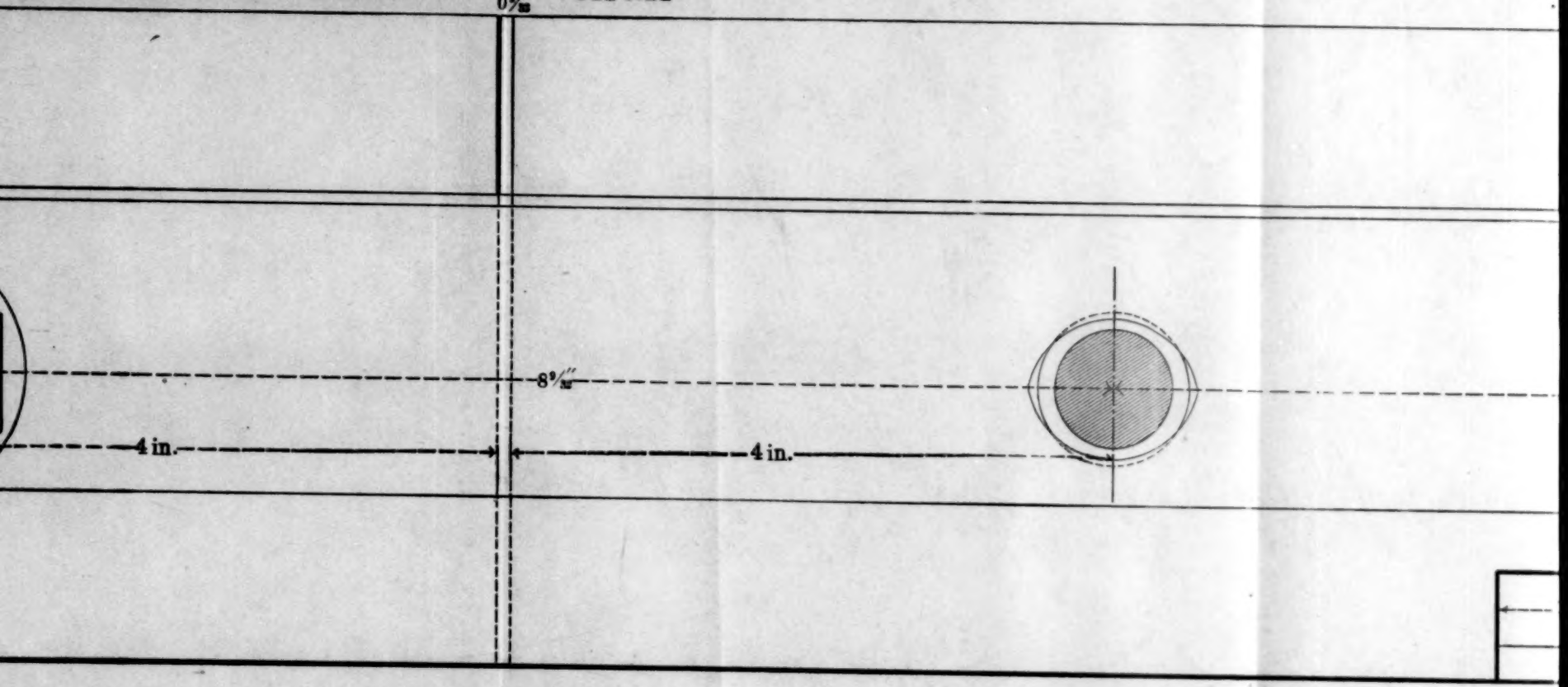

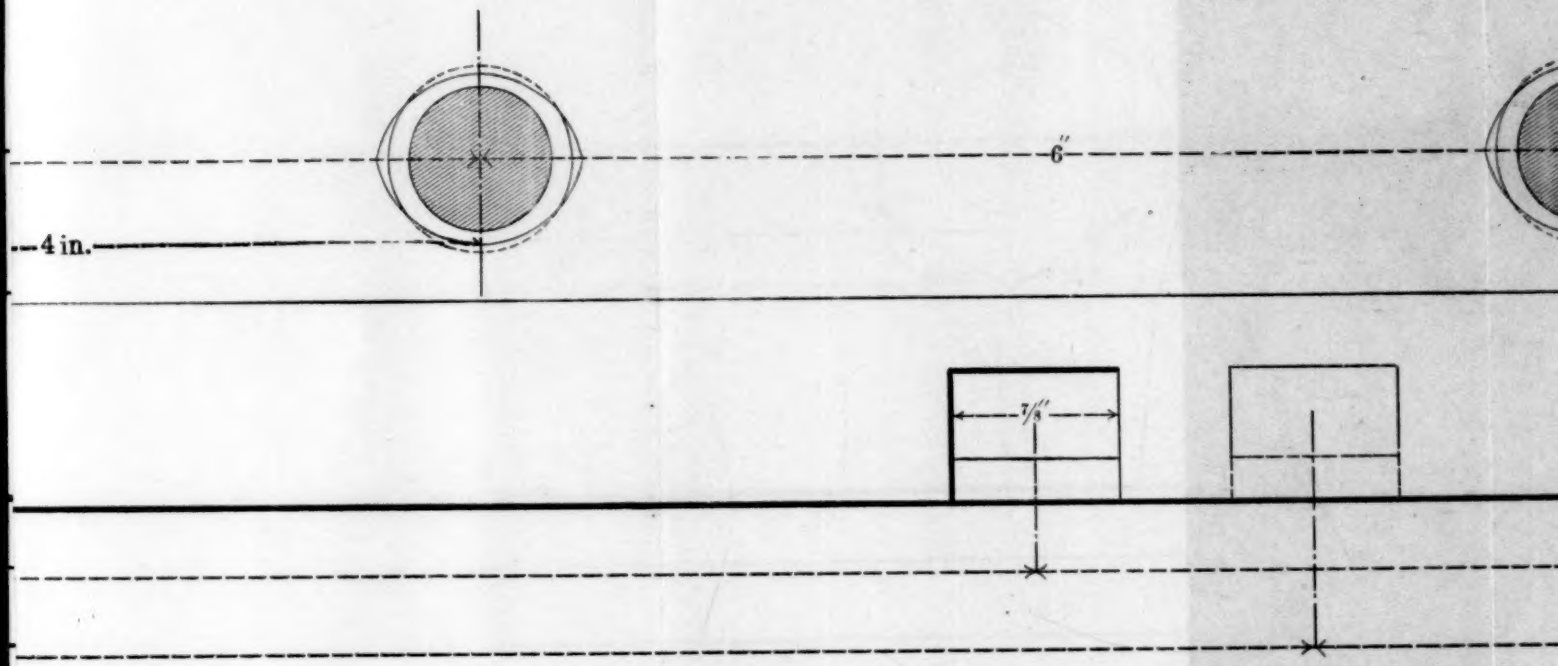
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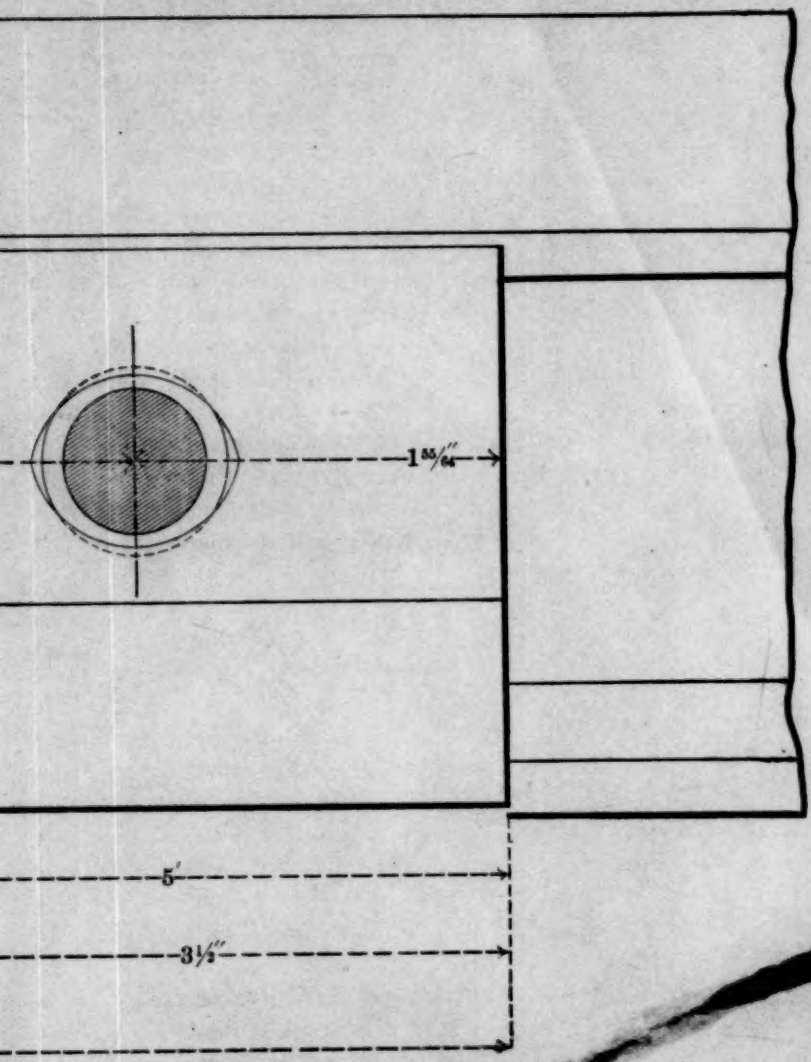
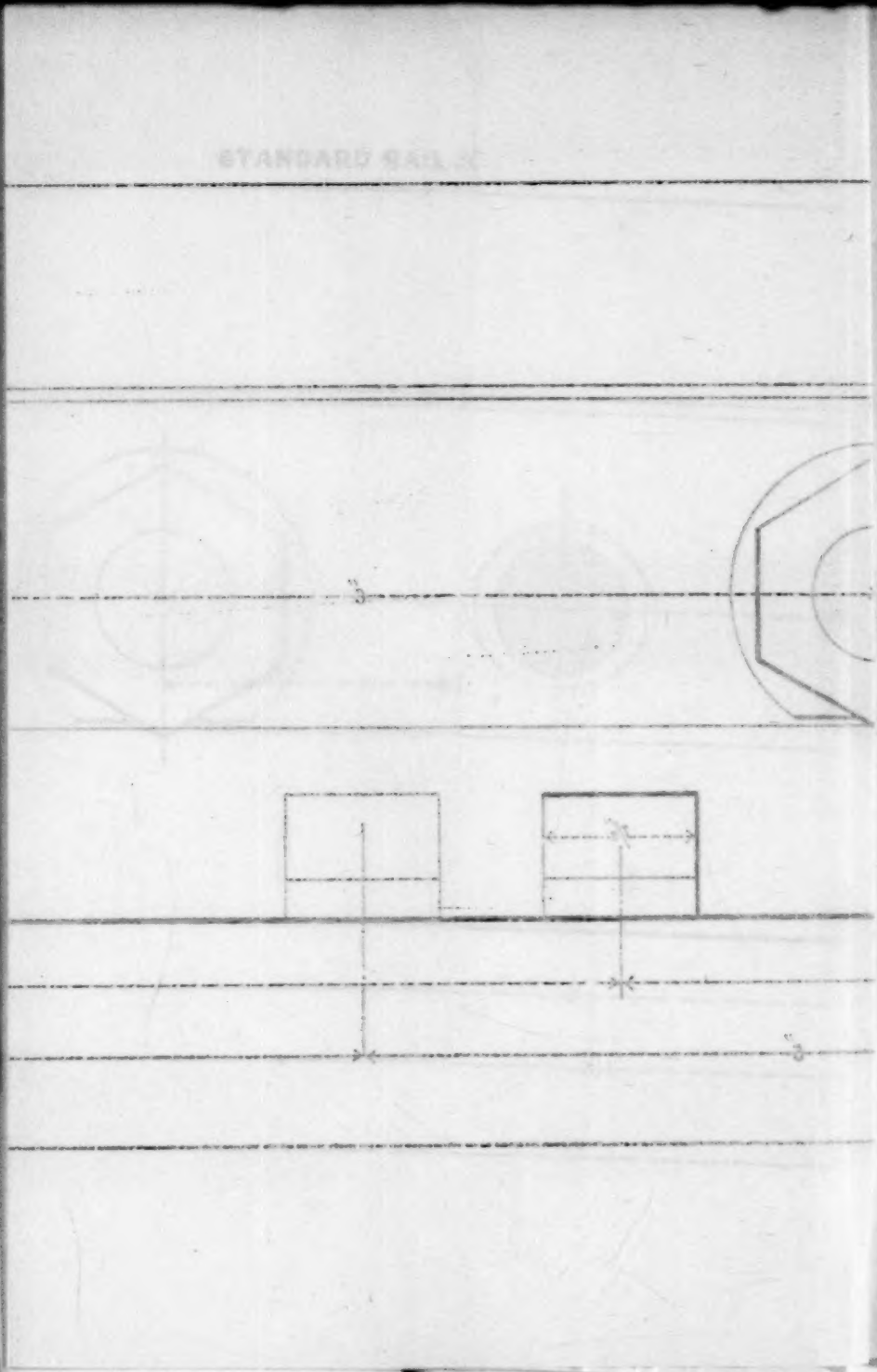

1 55/64"
5'
3½"



erable said tending to throw discredit on chemists and their work; and while I believe that there have been in the past, are now, and may be in the future, a good many poor chemical analyses made, I also believe that chemists are, as a rule, as honest and competent as gentlemen who belong to other professions. There are chemists who are chemists, and chemists who are not chemists.

The determination of manganese has been called in question. Now I think the chemist at almost every steel works in the country will tell you that, in his experience, the manganese differs in different parts of the same ingot. Mr. T. T. Morrell, chemist of the Cambria Iron Company, whom I believe to be a thoroughly competent and honest chemist, tells me that he has often found different amounts of manganese in different parts of the same ingot. Come with me to Altoona, and I will take you into the machine shop where steel is being cut and shaped, and I will show you that it is often necessary to stop the lathe or planer and take a cold chisel to cut out a hard spot, or else run the risk of breaking the tool. This hard spot is simply a part of the spiegel which is not thoroughly mixed with the mass when the steel is made. In the rapid methods by which steel is at present manufactured time enough is not allowed for the spiegel to become uniformly mixed. What wonder, then, that chemists find different amounts of manganese in what is supposed to be, but is not, the same steel. Indeed, I believe it is possible for the borings from one bore hole in the same ingot to be given to two chemists and to have them find different amounts of manganese, and yet both analyses be correct. And so I say to the steel makers, "Make uniform steel, and we, as chemists, will tell you what there is in it."

With regard to the determinations of manganese in the series of rails we are discussing I would say, I wish Mr. Wells was here, that you might see him for yourselves. When I began this work, I wrote to my old instructor in chemistry, Professor O. D. Allen, of the Sheffield Scientific School, to recommend me some one to help me. He replied that if Mr. Wells would come he could heartily recommend him. He had had two years' experience since his graduation, and, said Professor Allen, "I regard him as the best analytical chemist that has graduated under me." And I may add that both Professor Drown and myself graduated under Professor Allen.

Still further, it is simply impossible that any errors, either in the chemical analyses or the physical tests, should have had any influence

in establishing the point that the softer steel gives the better wear. This follows from the way in which the work was done. First the physical tests were made, then the analyses, then the tonnage was computed, and finally the loss of metal was determined. So that we knew nothing about a rail until all the chemical analyses and physical tests were made. Furthermore, some of the rails that were selected as faster-wearing rails, when we came to get the rate of wear, were found to be slower-wearing rails. So that no previous bias of mind, or, as it seems to me, no possible errors in the work could influence the result.

Again, with regard to sulphur and copper, it is said that these are of vital importance, and should have been determined. In answer to this I would say: Where is the man that can affirm, and back his statement by any analysis, that sulphur and copper have any influence on the wearing capacity of steel? I do not say that these elements do not have an influence on wear, but when this investigation was started the best information that I could get was that sulphur and copper were of vastly more importance to the steel manufacturers than they were to the consumer. And so I say that I believe the sulphur and copper are of importance to the makers of steel, but of not so much importance to one studying its wearing capacity. If you want to know the sulphur and copper in these rails you may determine them.

Probably no one has thought over the question why some of the rails in this series seem to be exceptions to the general law more than I have. This suggestion in regard to sulphur and copper, and other undetermined substances, and especially, in my judgment, oxide of iron, furnishes a possible solution of the problem. If we knew every foreign substance which these rails contain I doubt not but that some of the anomalies would be explained. And I would here like to ask chemists who have time to devote to such studies, to give us a method for determining oxide of iron in steel.

Another point made was the influence of heavier locomotives and cars on the wear of rails. If I understand this criticism it is this: Your slower-wearing rails had lighter-wheel tonnage for at least a portion of their life—the earlier portion—while your faster-wearing rails have had almost altogether heavier-wheel tonnage. In reply, I say the slower-wearing rails had during the latter part of their life the same heavier-wheel tonnage that the faster-wearing had. All the rails were taken out of the track at the same time, and, consequently,

so far as I can see, the comparison of the wearing capacity of steel with its quality is strictly a fair one.

Again, in the course of this discussion—not a few times—the exceptional cases, the cases where individual rails did not conform to the general law, have been taken out and held up prominently before us, as though these individual and exceptional cases were the only thing we should consider. Now, I submit to you that this is simply trying to overthrow a law by the exceptions to it, or, in other words, to nullify the teachings of a large number of samples by the teachings of a few exceptional cases, and I submit still further that this method of proceeding is neither good logic, nor fair, sound deduction.

I must not omit to comment on the remarks of those speakers who have refuted conclusions which I did not advance, and have then considered my position, namely, that the softer rails give the better wear, as completely demolished. A notable case of this kind is Mr. Kent, who, because he does not find that there is a direct relation between the loss of metal and the carbon, phosphorus, silicon or manganese, or phosphorus units in this series of rails, affirms that I have not solved the whole problem of wear, and, *ergo*, the softer rails do not give the better wear. I beg to remind him that I have never said that I had solved the problem of wear. I expressly say I have not solved it, but I do not see how that affects the main question; nor do I see, because there is no direct relation between carbon and loss of metal, that it is impossible for me to take a series of rails which have been in service and find by a study of them what chemical composition and what physical properties are, in general, characteristic of those rails which have given the best service. This I claim to have done, and the conclusion seems to me so plain that he who runs may read, namely, that the softer rails give the better wear.

With regard to Mr. Metcalf and his attributing all the troubles of steel to nitrogen, I think it may fairly be said, first, that Mr. Metcalf brings no proof to show that nitrogen is the bane of steel; and second, if it is, the natural conclusion would be that no steel could be made except by the crucible process, which would undoubtedly be a satisfactory conclusion for crucible steelmakers, like Mr. Metcalf, but would hardly satisfy the stockholders of the Bessemer works, or stop their making steel with nitrogen in it in the future. With regard to another criticism of Mr. Metcalf's, that the question of flow had not been considered, I would say that I think there is very little evidence of

flow in this series of rails anyway. And so I asked Mr. Metcalf how the flow influenced the loss of metal by wear. He replied that flow squeezes the metal toward the flange and then the flange rubs it off. To this I made reply, that the flow, whatever there is of it, must be away from the forces which produce it. Now, both the pressure of the flange against the rail and the coning of the wheels would cause the metal to flow away from the flanges instead of toward them, and consequently I do not see how you are going to get metal there for the flange to rub off. The flow must be in the other direction, or away from the flanges. Although a few of the rails in this series give evidence of having a little metal pushed off out of place by reason of flow, yet the metal is there. It is not worn off, and the question we are studying is loss of metal by wear.

One or two points further, and I am done. It has been said, "You have not exhausted the question yet. More study must be put upon it." No one is more conscious of the truth of these statements than I. I do not pretend to have exhausted the question. I wish there were fifty workers in this field. But I believe that the results that we are discussing are the best information that we now have upon the question as to the relation between the wearing capacity of steel and its chemistry and physics. I would not at all affirm that this will be the best information on the subject five years from now. But I think that man does his life-work best who lives up to all the light that he has in his own time. And so I ask you to utilize this work, to act upon it and guide your practice by it until something better is obtained.

Finally, I have been accused of trying to teach the steelmakers how to make steel, and it is to be supposed that they know already much more about that point than I do. Now, if any one thinks that such has been my aim, or has ever been in my thoughts, he has certainly misunderstood me. What I am striving for is to tell the steelmakers what we want, not how to supply this want. This whole question of the fitness of material for the purpose for which it is intended is in its infancy. We are doing something toward studying it at Altoona. The principle which governs us there is that the kind of service that is to be required of the metal must determine what kind of metal shall be used. Because softer steel gives better rails, we do not think softer steel will give better crank-pins. In crank-pins we require stiffness, which comes with harder

steel. But in rails, in tires, in bridge rods and in boiler plate we are, so far as our knowledge now goes, inclined toward soft steel. And all the information which we have thus far been able to accumulate in regard to these kinds of service confirms our position and justifies our conclusion.

And now, how can the best results be obtained in trying to decide upon the quality of material best fitted for any kind of service? I do not see that the steelmakers can study this question alone, for after the steel leaves their hands they know very little of its behavior. It does not come under their personal observation and study. It seems to me, therefore, that the question can only be studied by both the consumer and the producer working together. I cannot but regard that the interests of the consumer and the producer in this matter are one, that neither can solve the question alone, and so I ask you to work with, rather than oppose me, to utilize the information that is gained, so far as it is gained, and to constantly hold in mind the necessary dependence of both producer and consumer upon each other.

Velocity of Light and Electricity. The probable identity of wave velocity in light and electricity has been established in various ways. Weber and Kohlrausch measured the quantity; Sir William Thompson and J. Clerk Maxwell experimented upon the electromotive force; Ayrton and Perry operated upon the electrostatic capacity. The extreme range of velocity in the various results was about 10 per cent.; the mean of all the results appear to correspond precisely with the velocity of light. The meaning of this accordance may be explained as follows: Suppose two parallel plain surfaces, each charged with a unit of positive electricity and placed at unit of distance; they will repel each other with a unit of force. Now suppose that they are both set in motion in the same direction, but remaining parallel and at the same distance; they will produce the effects of two parallel currents of the same kind and will exert a mutual attraction which will increase with the velocity of motion. It is possible to conceive of a velocity such that the attraction resulting from the motion will exactly counterbalance the repulsion which arises from the similitude of electricity; this velocity is precisely that of light.—*La Lumiere Electrique.* C.

BURNISHING AND DUCTILIZING STEEL.

By Jacob Reese, Pittsburgh, Pa.

Read at the Philadelphia Meeting of the American Institute of Mining Engineers, held at the Franklin Institute, February 17, 1881.

I have discovered a new method by which steel and other metals may be burnished by the automatic action of the burnishing machine, and by which the cost is greatly diminished and more perfect work produced. And in addition to the polishing and burnishing action of

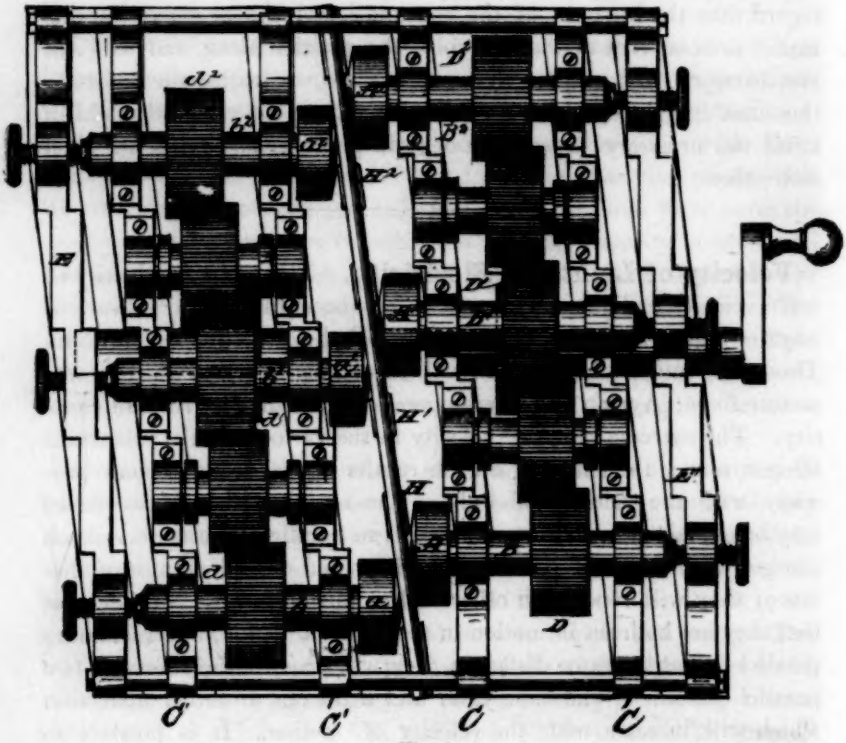


Fig. 1.

the new process, I have discovered that by a certain practice in the process of burnishing, the metal under treatment may be permanently increased in diameter of its cross section, and its ductibility increased

from 30 to 90 per cent. at a temperature ranging from 60° to 250° Fahr.

The machine is shown in the accompanying drawings; Fig. 1 is a

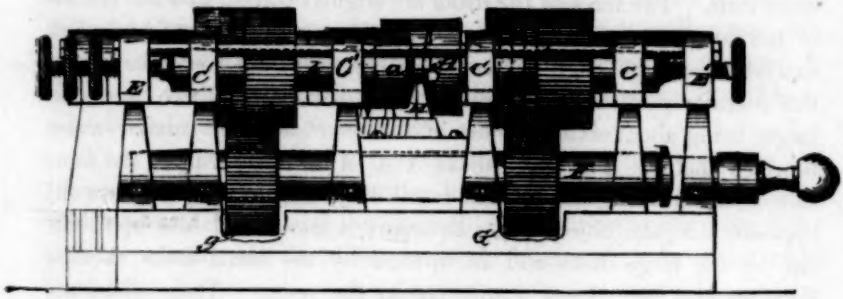


Fig. 2.

top view of a continuous-disk machine, Fig. 2 is an end elevation of the same, Fig. 3 is a top view of a set of conical disks and Fig. 4 is a

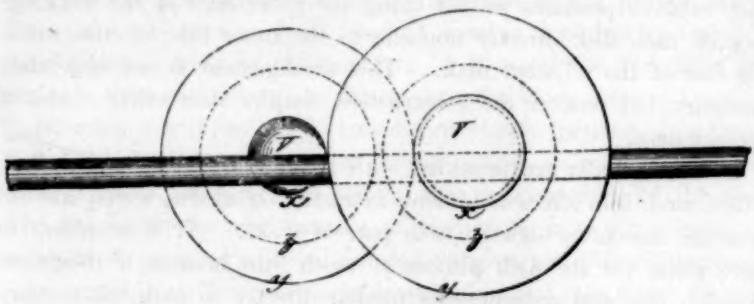


Fig. 3.

diagram showing the working face of one disk and the back of another. Like letters refer to like parts wherever they occur.

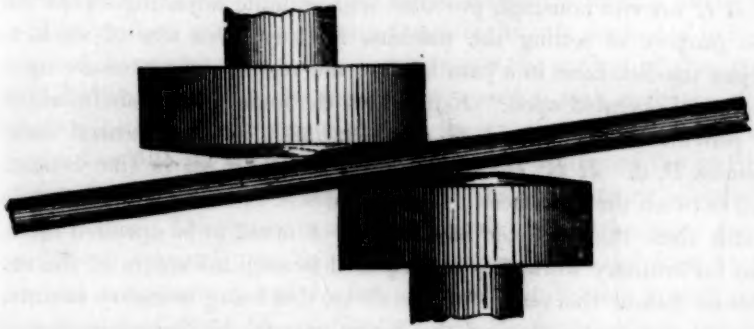


Fig. 4.

The series of disks, which in the present instance are six in number, are arranged so that they all operate upon the bar at one and the same time. The faces of the disks are slightly conical and the centres of the faces are turned concave, so that the working-face of each disk extends from the edge of the periphery to the outer edge or line of the concave portion of the disk. The disks are of two sizes, the larger being about sixteen inches in diameter and the smaller about fourteen inches. The large disks A A' A^2 are placed upon the same side of the working-line and the small disks a a' a^2 are placed on the opposite side, the object being to secure a downward bite upon the bar by the large disks and an upward by the small disks, thereby keeping the bar down firmly on to the rests. These disks are mounted on suitable shafts B B' B^2 and b b' b^2, which are set in the standards or housings C and C' in such a manner that the large and small disks are not directly opposite to each other, but bear such relative positions as will bring the outer edge of the working-face of each disk directly opposite to the inner line of the working-face of the adjacent disk. This arrangement is not absolutely necessary, but renders the construction simpler than other modes of arrangement.

The disk-shafts are provided with pinions D D' D^2 and d d' d^2, which mesh into idlers or pinions mounted on shafts, which are set into the standards between each pair of disks. It is necessary to have idlers for the disk pinions to mesh into, because if they were to mesh into and communicate motion directly to each other every other disk on the same side of the working-line would revolve in an opposite direction, and consequently prevent the mechanism from working.

E E' are end housings, provided with suitable adjusting-screws for the purpose of setting the machine for any given size of work, to adjust the disk-faces in a parallel line and regulate the pressure upon the metal operated upon. F indicates the main driving-shaft, which is provided with pinions G, g, which mesh into the central disk-pinions D, d. H H' H^2 indicate rests, which are set in line beneath and between the disk-faces. These guides or rests are slightly less in width than the diameter of the piece of metal to be operated upon, and for ordinary work they are adjusted to keep the centre of the bar a little below the centre of the disks, that being necessary in order that the resultant action of the forces exerted by the movement of

the disks may cause the bar to feed forward as it rotates. The forward speed will depend upon the altitude of the rests in relation to the disk-centres, and if they are adjusted so that the centre of the bar is on the same line as the centre of the disks it will rotate, but without forward or backward motion. If the rests are adjusted to throw the centre of the bar above the centre of the disks, it will have a backward movement as it rotates.

When power is applied to the main shaft *F*, to rotate the same, the pinions *G g* communicate motion to the central disk-pinions *D d*, which turn the idlers and thus communicate motion to the other disk-pinions, causing all the disks to rotate uniformly. In order to fit these disks for burnishing and ductilizing iron and steel it is necessary that their working-faces should be trued and highly polished, and this I accomplish in the following manner:

The machine having been adjusted for any given size of work and the guides or rests being in a line and adjusted to the proper height, I take a square piece of hard wood of suitable thickness and place it upon a rest in front of the machine. I then oil the disk-faces and sprinkle them with emery and finally enter the block between the disk-faces, when it will be caught and drawn slowly forward, thus truing and polishing the entire train of working-faces at one and the same time, and also polishing and truing the working-faces of the rests. The machinery is now capable of burnishing and ductilizing the metal when properly adjusted for that purpose, and this adjustment is a matter which will require considerable skill and care upon the part of the operator, as a degree of pressure is necessary in some cases which would be entirely inadmissible in others.

By referring to the drawings it will be readily understood that when the rests are adjusted to any given height the feeding of the bar will be uniform and constant, and therefore the only method of increasing and decreasing the frictional action upon the surface of the metal will be by regulating the pressure as occasion may require. The greater the friction the greater will be the tractive force which tends to draw or film the surface of the metal. The ability of the metal to resist this drawing force depends upon the attraction or cohesion of its particles. This varies in different metals and in the same metals at different temperatures, being greatest at the lowest and least at the highest temperature; and in iron and steel it depends greatly upon the amount of carbon in combination with the metal. Now, it is evi-

dent that when the bar is put into the machine its temperature will be gradually raised by the frictional action at each successive pass, and therefore become less and less able to resist the tractive force, and that as its temperature increases the metal will gradually expand in diameter, so that if all the faces are previously adjusted to exactly the same distance apart, not only will the metal become less able to resist the tractive or drawing force, but the increased temperature of the metals will, by causing such expansion, develop more pressure and frictional tractive force, so that the metal will then be very liable to draw or scab. The disk-faces should therefore be so adjusted as to bring the greatest pressure at the first pass and to apply a little less at each successive pass until the burnished bar is completed.

In conducting the operation the object is to secure sufficient pressure to compress the inequalities and to develop enough frictional or tractive force to overcome the attraction of cohesion of the particles composing the scale on the surface of the metal, yet not enough to overcome the force of cohesion of the particles which will then form the surface of the metal itself. If the metal has a great force of cohesion and does not possess a tough, tenacious scale, this may be readily effected; but where the conditions are opposite great care must be had and a constant watch kept for signs of filming. Therefore, as it is imperatively necessary that certain degrees only of pressure, frictional action and tractive force be applied or developed upon the surface of the metal, it is necessary, first, that the metal should have been previously rolled to an exact or uniform gauge, so that when burnishing an undue amount of pressure may not be developed upon its surface at any point; secondly, as the ability of the metal to resist the tractive force is less when at high temperatures, it should be operated upon when in a cold state, or at a temperature not exceeding 500° F.

The machine being in condition, having its working-faces trued and polished, and the metal having been properly prepared by rolling to an exact gauge, a test-bar may be entered and the working-faces gradually tightened up after each pass until a point is reached at which the films begin to show upon its surface. This is an indication that the pressure is too great, and the tightening-screws should be relieved a little and the test-bar again entered, a careful watch being kept for further filming. If none appears the machine is properly adjusted for that sized bar; but if films still continue to form, the pressure

must be further decreased until a point is reached at which no films are formed. It is not necessary, however, that the machine should always be adjusted in the manner just described, as burnished bars may be sometimes produced, although a very light pressure is used, as, for instance, where the scale upon the metal is not tenacious and the surface of the metal is very smooth; but in all cases the pressure will be light in comparison with that which is required for rolling and extremely light when compared with that required for cold-rolling. I am unable to give the required degree which will be necessary in all cases, as I find that the pressure varies upon any given point, according to the difference in the diameters of the bars operated upon, the larger diameters burnishing under heavier pressure than the smaller; and, moreover, the pressure upon any given point may vary accordingly as the width of the burnishing-faces used varies. The wider the disk-faces the greater will be the amount of frictional action and tractive force upon any given part of the bar in any given time, and consequently the less must be the pressure. The converse of the proposition is also true, viz., the narrower the disk-faces the less the frictional action and the greater the pressure admissible; but the working-faces must never be made very narrow, as in such case so great a pressure would be required to develop the frictional action which is necessary that the operation would be entirely changed and cause a reduction of the metal and displacement of its particles, as in rolling. Finally, I find that the pressure may vary with the different temperatures and natures of the metal operated upon. Therefore no precise rule can be adhered to for all cases, except, first, to have all stock previously rolled to a uniform gauge; secondly, to have all the burnishing-faces turned perfectly true with a high polish; thirdly, to have the burnishing-faces constructed of sufficient width to develop a sufficient amount of frictional action when a light pressure is applied. Then feed the bar at a proper temperature and apply the pressure from an exceedingly light one to the highest the metal will stand without filming.

The machine being in the condition specified and adjusted as specified, rough bars of metal in a cold state are inserted, one at a time, between the receiving-disks. They are caught, rotated rapidly and drawn forward, traveling forward with a speed of from one to sixty feet per minute, according to the size of the bar, height of the rests and speed at which the disks rotate, and are delivered per-

fectly straight, of a true cylindrical form and highly burnished. In some cases, however, when the bars are of a large diameter and are covered with a tough, tenacious scale, additional passes may be required to accomplish this result.

When burnishing cold metallic bars, I prefer to place narrow pans, containing petroleum or other oil, beneath the second and third pair of disks. These pans are of sufficient size to contain the required quantity of oil and are shaped so as to form a sheath or trough, in which the lower portions of the disks revolve. The effect of the application of the oil is to prevent the working-faces of the disks from scratching and marring, and it also has a certain effect upon the finished product, of which I shall speak hereafter.

When it is designed to straighten and burnish metal directly as it comes from the rolls during its manufacture, the process should be the same as before specified, except that the metal should be allowed to cool to a dark red heat and a considerable quantity of water should be let upon the first set of disks and upon the bar, to reduce the temperature of the metal to the proper degree, so that in its rapid contraction the scale will be loosened. A steam or air blast should be used to carry the scale away, and the first and second set of disks will then readily remove any portion of scale which may still adhere to the bar. The metal will then pass from the first to the second set of disks, thoroughly cleaned and partially burnished and the second and third pair of disks will, by the frictional action, which also burnishes, heat the surface of the bar. Consequently, the lighter components of the oil will be vaporized, leaving the bar coated with carbonaceous matter, which is apparently forced into the pores of the metal by the action of the disks, and the bar, when burnished, is found to have a much finer appearance than if it had been burnished without the oil, and it is also enabled to resist oxidation to a greater degree.

For the purpose of illustrating the frictional action which may be obtained by the employment of disk-rolls, I will again refer to the drawings, in which Fig. 3 represents a top view and Fig. 4 is a diagram of a set of disk-rolls, the latter showing the back of a sixteen-inch and the working-face of a fourteen-inch disk. *V* indicates the concave portion of the disk-faces, which is five inches in diameter in the fourteen- and seven inches in diameter in the sixteen-inch disk. *x* indicates the inner lines or edges of the working-

faces; *z* the neutral lines, or those portions of the disks at which their rate of speed when working is equal to the surface speed of the bar in rotating; and *y* the outer edges or lines of the working-faces of the disks at their peripheries. It is well understood that the different portions of the disk-faces travel at different rates of surface speed, according to their position with relation to the disk-centres.

When a cylindrical bar is fed into the disks it will rotate, and, all portions of the surface of the bar being at the same distance from the axis or centre, will travel at the same surface rate of speed, and as the working-faces of the disks travel, having differential rates of surface speed, as before stated, great frictional action is produced on the working-surface of the disks and the surface of the bar; or, in other words, this result follows because the surface speed of the bar and disk-faces is the same only on the theoretical or neutral lines indicated by the letter *z*, the disk-faces traveling at a gradually increasing speed from the neutral line to the peripheries and at a gradually decreasing speed from the neutral line to the inner lines of the working-faces of the disks. If, therefore, as in ordinary practice, the working-faces of the disks are four inches in width from the outer to the inner edges of the working-faces, the area of the small disk will be $113\frac{26}{1000}$ square inches, and that of the large disk $138\frac{220}{1000}$ square inches, thus making a total area of $251\frac{316}{1000}$ square inches of frictional surface which slips or rubs over the surface of the bar at each revolution of the disks.

In addition to the frictional action of the disk there is that of the rests. A bar one and one-eighth inches in diameter will rotate (the rests being at the proper height) eight times to each revolution of the disks and feed forward about two inches to each revolution of the disks, or one-quarter of an inch to each revolution around its own axis. The length of the rest's working-surface is usually about five inches, so that the bar will revolve twenty times over the polished surface of the rest during the time any given portion of it passes from one end to another of the rest, and the rest acts the same as if the bar were rotated in a lathe and a burnishing-tool pressed against it with the same degree of force during twenty revolutions around its axis. Finally, there is the frictional action which arises from the forward movement of the bar over the burnishing-disks and rests.

One of the effects produced by the frictional action to which I have referred, or by the action of the heat developed by the friction, is to gradually expand the metal during the burnishing operation, so that as the bar travels forward the pressure will become augmented, unless the tightening-screws are adjusted lighter for the latter passes; and I have found that, when they are properly adjusted, the metal will in some cases retain permanently its increased diameter, which I have found in all cases to indicate a slightly decreased tensile strength, elastic limit and a greatly increased ductility in the metal. When, however, the tightening-screws were adjusted so as to compel the bar to retain its original diameter, I have found the elastic limit and ductility are the same as in the original state, and that the tensile strength remains almost the same as in the original state previous to the operation.

The following record of tests made by tension shows clearly the changes which are effected in the physical nature of the metal by the process:

Marks and Condition of Pieces.	Original Diameter.	Diameter after Fracture.	Original Cross-Section.	Cross-Section after Fracture.	Elastic Limit.	Elastic Limit per Square Inch.	Tensile Strength.	Tensile Strength per Sq. Inch Original Section.	Elongation in Five Inches.	Elongation.
	In.	In.	Sq. In.	Sq. In.	Pounds.	Pounds.	Pounds.	Pounds.	In.	Per Cent.
459 Rough	1·013	·855	·806	·716	51,000	63,283	88,235	109,486	·547	10·94
460 Bright	1·014	·853	·807	·571	47,500	58,823	86,795	107,486	·953	19·06
461 Bright	1·016	·851	·811	·569	49,500	61,058	88,395	109,035	·797	15·94
4·2 Bright	1·012	·969	·804	·737	48,000	59,674	88,305	109,782	·500	10·00
463 Bright	1·015	·910	·809	·650	47,500	58,704	87,365	107,972	·656	13·12
464 Rough	1·012	·952	·804	·712	48,000	59,674	87,500	108,782	·500	10·00

Nos. 459, 460 and 461 were cut from the same bar of steel. No. 459 was cut from the rough end, which was in the same condition as it came from the rolling-mill. Nos. 460 and 461 were bright, and were cut from the end that had been burnished. No. 459 broke just above the top centre punch-mark. No. 460 broke between the points of measurement. No. 461 broke at the top centre punch-mark.

Nos. 462, 463 and 464 were cut from one bar of steel, each end of which had been burnished. No. 464 was cut from the middle of the bar, which was rough as it came from the rolling-mill. No. 462 was cut from one end, and No. 463 from the other end, both of which had been burnished. No. 462 broke one and one-half inches above the top centre punch-mark. No. 463 broke one-half inch below the top centre punch-mark. No. 464 broke one inch above the top centre punch-mark. No. 462 did not break at its smallest diameter, which was midway between the points of measurements.

All the changes or phenomena which present themselves in the finished product show that the operation to which it has been subjected embodies some principle which has never before shown its effects in the product of any rolling, hammering or compressing operation, nor in the product of any burnishing, brightening or polishing operation known heretofore to the art of metallurgy. For instance, that indicated by the permanent increase in the diameter of the metal, although at the time it is confined between parallel surfaces and under pressure, the operation being conducted so that the heat developed does not generally exceed 250° Fahrenheit, which would not be sufficient, no matter how long continued, to anneal or ductilize heavy cold bars of steel by any known process.

When steel is required for structural purposes, it must be able to resist concussion, sudden shocks, rapid vibration and deflection, and give due warning, before final rupture takes place, by elongating within certain degrees. Consequently, heretofore, the steel has been made low in carbon to secure the required ductility, and therefore possessed a low tensile strength. The steel is annealed after its manufacture, to bring it back to its normal condition, and destroy in a measure the effects produced in its physical structure by the ordinary rolling operation, since all rolling, hammering and drawing leave the physical structure of the metal in an abnormal condition, produc-

ing hardness, brittleness and liability to rupture from concussion, vibration or rapid deflection.

Annealing steel reduces its ability to resist tensile, compressive and torsional strain, as well as its elastic limit, and increases its elongation or ductility. It is a slow operation, lasting generally from five to twenty-four hours, and leaves the metal covered with scale. By my process the ductility of the metal may be greatly increased without the formation of a scale upon its surface, and in a very rapid manner. In comparing it with ordinary annealing operations the following facts become apparent:

First. As the metal is previously rolled to an exact size, and the disk-faces are adjusted to exert exactly the same degree of pressure and frictional action upon all parts of the bar, the ductility of the metal should be constant and uniform at all points, whereas in annealing the temperature of the furnace varies at different parts, consequently the metal cannot be uniformly annealed.

Second. As the bars are all of the same size previous to the burnishing operations, the same degree of ductilizing action should be had upon each, and consequently they should all be regularly ductilized, whereas in annealing, the process is not automatic, and the bars are charged and drawn by hand, so that they are exposed to heat for irregular periods of time.

Third. The ductilizing effect is produced by this process at a heat never exceeding 500° Fahrenheit, and this is too low to deprive the bar of carbon; or, if it does so to any extent, it does it uniformly, whereas in annealing the bar loses considerable carbon, and loses it unequally, so that not only is the tensile strength reduced considerably, but it varies at different points of the bar.

Fourth. As the ductilizing of the metal is constant and uniform, its internal strains should be regularly and uniformly relieved, whereas in annealing the temperature always varies in different parts of the bar; hence its internal strains should be irregularly relieved.

Fifth. As the temperature in this process is very low and uniform upon all parts of the bar it remains perfectly straight in cooling, whereas in annealing the high and uneven temperature of the metal causes it to warp and become distorted in cooling.

Sixth. By my process I am enabled to ductilize metal at the rate of

one foot per second to one foot per minute, whereas annealing operations require several hours or days for their completion.

This process will be found to be peculiarly adapted to the production of steel shafting, piston rods, and also for very light work, such as burnished steel for pivots for watches and clocks, etc., in which latter case it is evident that the mechanism employed must be of a reduced size suitable for the work to be accomplished.

Comparing the mechanical effect of this process with other well-known processes, the difference is very marked. Wrought iron possessing a tensile strength of 50,000 pounds per square inch, and an elastic limit of 30,000 pounds per square inch, and exhibiting an elongation of 25 per cent., will, when cold-rolled by the Lauth process, possess a tensile strength of 68,600 pounds, and an elastic limit of 59,600 pounds, but the ductility is reduced to an elongation of 6 per cent. When such cold-rolled iron is annealed it is found to possess a tensile strength of 48,700 pounds, an elastic limit of 32,000, and an elongation of 15 per cent.

Professor R. H. Thurston, in his paper on "Mechanical Treatment of Metals,"* said: "All known and actually practiced methods of so altering the character of the metals used by the engineer, involve, directly or indirectly, the elevation of the original elastic limit of the material." In this process, however, the elastic limit is slightly reduced.

In conclusion I would add, that the phenomena exhibited in this process invite further research into the laws of molecular physics.

Electric Light in the French Lighthouses.—Four of the most important French lighthouses have already been provided with very powerful electric apparatus and with machinery for furnishing sound signals during stormy or misty weather. It is proposed to apply similar apparatus to the forty-two others. The total cost is estimated at 7,000,000 francs ($1,400,000) for the electricity, and 1,000,000 francs ($200,000) for the fog horns. This expenditure is very light in view of the protection which it will afford to the immense capital represented by the 225,000 ships which annually visit the French harbors.—*Les Mondes.* C.

* *Metallurgical Review*, vol. i, page 1.

INDUSTRIAL EDUCATION FROM A BUSINESS STANDPOINT.

By JOHN S. CLARK.

An Address delivered before the Philadelphia Board of Trade and the Franklin Institute, June 6th, 1881. With additions by the author.

If I were to come before your Board of Trade with a statement that there had been discovered within easy access of Philadelphia a bed of iron ore, of vast extent, and of a quality far superior to any known deposit, if I could support this statement by the testimony of eminent mining engineers, if I should submit to you samples of iron and steel manufactured from this ore, and should produce vouchers from experts as to their superior excellence; and if I should further announce that the Baldwin Locomotive Works and the Phœnix Iron Works were ready to accept the product of this ore for their supplies, —I think there is very little doubt but that sufficient capital could be found here in Philadelphia to develop the enterprise. In accepting your invitation to speak before your Board of Trade this evening, I desire to present a subject of far greater importance to the material interests of this city and State than all the mineral wealth of the district; and if I cannot justify liberal expenditures in promoting it on grounds as substantial, tangible and practical as can be urged for investment in any of the mining enterprises of the State, I shall have entirely failed in my argument.

Before entering into the details of the discussion I wish to say a word or two in explanation of the term value, a term which I shall have frequent occasion to use. In a commercial sense, value means the price or worth of the thing bought or sold; in economic science—setting aside for the time being any discussion of the effect of supply and demand upon value—the value of an article may be said to depend upon the original value of the raw material and the value of the labor which has been expended upon it. And, further, the original value of the raw material is usually so slight that we may say, speaking broadly, that any particular value set upon an article, such as $1 or $10, means that an equivalent amount of human labor has been, as it were, detached from the indi-

vidual, concreted and put into definite shape for exchangeable purposes. One step further: human labor is but the expression of human thought. From the rudest kind of labor—labor which expresses hardly more than the force of mere animal push or pull—to the labor of the designer, the artist or the poet, all is but the expression of that wonderful human force which we call thought. Thus much being true, we reach the conclusion that human thought, as expressed by human labor, constitutes the principal factor in all values. As the full discussion of this statement will lead us to some important educational, commercial, and political considerations, I desire to make the point perfectly clear, and therefore invite your attention to a few illustrations of the manner in which thought creates values.

I hold in my hand a piece of steel. Its value is perhaps five cents. As yet it may be said to represent hardly more than so much raw material. In this hand I hold another piece of steel, of a similar quality, but less in quantity, and yet this latter has a value of twenty dollars. What makes this difference in value? Simply this, that human thought has been playing, as it were, about this latter piece of steel, and has made it the basis upon which it has concreted itself, so that we have an instrument of great practical use, a micrometer caliper—mainly the product of thought as expressed by skilled labor. Take this copper lamp. Here, again, we have perhaps ten cents' worth of raw material, carrying a value of five dollars, four dollars and ninety cents of which expresses the value which has been created by thought or skilled labor. In this porcelain vase observe how an insignificant value of raw material is made to carry a still greater value, created by thought. In this instance, we have a few cents' worth of clay transformed by skilled labor into a work of art, and carrying a value of over fifty dollars. Again, in these pieces of cotton goods, and in these Hamburg edgings, we have a few cents' worth of raw material, cotton, carrying values, created by skilled labor, a thousand fold greater than the value of the raw material itself. If we examine industrial products in any department, we find the same condition of things holds true—that the main value in the things made is the product of human thought.

As an extreme illustration of the great value of thought which iron and steel can convey let me quote the following calculation made by Dr. George Woods, of Pittsburg:

Seventy-five cents' worth of iron ore may be made into:

Bar iron, worth	$5 00
Horse shoes, worth	10 50
Table knives, worth	180 00
Fine needles, worth	6,800 00
Shirt buttons, worth	29,480 00
Watch springs, worth	200,000 00
Hair sprins, worth	400,000 00
Pallet arbors, worth	2,577,595 00

It is also to be noted in this connection that thought has made itself felt in commerce in the production of articles of beauty as well as of use. This vase, whose absolute utility is no greater than that of a common earthenware pitcher, is rated in the market at a value many times that of a vase of ordinary form and color—and the value of beauty, which thought has created here, is just as important, commercially, in these days of our higher and more exacting civilization, as the value of use which thought has perfected in this micrometer caliper. We reach the conclusion, therefore, that in industrial articles, whether they be for use or for beauty, it is the value of the thought expended upon them which principally determines their commercial value. And if we extend our observations, we see that this state of things holds true all about us. The room in which we are assembled, the building of which it forms a part, the contents of this building—what has given to them the value which they represent? Certainly not the raw materials of which they are composed; rather it is the thought which the raw materials are carrying. Step out into your streets, observe the contents of your warehouses and your stores. You find thought expressed in finished products, and you find also food and materials on their way to serve as a supply to this thought as it labors in the expression of its ultimate purpose. Look further. In your machinery and wonderful mechanical contrivances you have this same human thought attaching itself to the elemental forces of the universe, and subduing steam, electricity, magnetism, to the common service of man. Now, it is human thought acting through human labor, and vivifying it with various degrees of intelligence and skill, that is accomplishing these myriad works, and creating these myriad values.

With these illustrations before us, and with this survey of objects which surround our daily lives, we must see plainly that there are two factors which enter into whatever is produced by human hands—raw

materials and the thought which has made use of these raw materials. And we see, further, that of these two factors, thought is by far the more important, material being simply the foundation, or the basis, upon which thought displays itself. Bearing these facts in mind, if we look at the enormous industrial forces which are gathering in England, France and the United States, and observe how human thought is displaying itself in these activities, we may, perhaps, realize something of the commercial changes which are taking place about us, and of the more important ones which are impending in the near future; and we may reach some appreciation of what thought really means as an article of commerce, and of the effect which the development of human thought in industrial directions is likely to produce, morally, socially and politically.

Take England, for example. The careful student of modern English history must look to the trade and commerce of Great Britain for the true explanation of the great political questions which now agitate the English people; indeed, the Irish question, and the still greater question of land tenure in England, which lies behind it, are matters which will ultimately be adjusted by the commerce of Great Britain, and it is the industrial element in this commerce upon which the other elements mainly depend. England will be able to hold her own and to overcome the many forces which are now setting against her only so long as she can maintain the industrial supremacy which she has secured by selling the thought of her people. When her manufactures fail, she will fail irretrievably in her commerce, and many of her institutions will share in that ruin.

Although England is perhaps the most striking example of national dependence upon the concretion of human thought, we find it to be true in all civilized countries of the first rank, that the elements which go to make up national power are centering more and more around the industrial forces. It is upon these industrial forces that the leading States now rely for the maintenance of their political as well as their commercial supremacy; it is through the immense activity of the industries that the four quarters of the globe are being probed for food and raw materials, that methods of transportation and distribution have been developed, and that the huge manufacturing centres which play so great a part in modern political economy have reached their present importance. Industrial development has become, indeed, a profound national question. Under these circumstances it is not out

of place for us to study with much care the industrial development of our own country.

For the purpose of bringing the matter concisely before your minds, let me invite your attention to a few commercial statistics in regard to the relative wealth which England, France, and the United States are creating by the concretion of human thought in industrial labor, and the bearing which this wealth has upon commerce:

ENGLAND.

	Imports.	Exports.
Raw material,	$784,236,980	$117,727 03
Food,	885,086,960	33,217 32
Manufactures,	174,894,340	854,093 19

FRANCE.

	Imports.	Exports.
Raw material,	$425,320,200	$250,838,600
Food,	364,721,800	
Manufactures,	84,183,600	347,098,200

UNITED STATES.

	Imports.	Exports.
Raw material,	$182,057,686	$310,900,287
Food,	215,219,419	439,996,838
Manufactures,	247,065,378	73,081,365

It will be observed in the exhibits of England and of France that it is the manufactures which give life to the commerce of each nation, consuming food and raw material on the one hand as imports, and exchanging manufactured products on the other, as exports.

An examination of these statistics shows us that in the markets of the world England and France are great sellers of the thought of their people, while the United States sells but $73,081,365 of thought, and buys foreign thought to the amount of $247,065,378. It is true that the industrial power of the United States appears at some disadvantage in this exhibit, owing to the fact that most of our manufactures are consumed in our home market; but while this table more than suggests the industrial advantages which we have over England and France, by reason of our supplies of food and raw materials, it also makes painfully evident the fact that, in proportion to our opportunities, we are far behind the other two nations in the extent and variety of our industrial development.

Our inferiority in this direction was everywhere noticeable at the Centennial. I remember having been called to the Exhibition in March, 1876, before the opening, and meeting in the Main Building the manager of a New Jersey pottery. He was jubilant over the glories of his exhibit, and the certainty which he felt of securing a high award. Being at the building a month later I met this New Jersey potter again. He was standing before the English and the French exhibits of porcelain and pottery then just uncovered. I found he had experienced a complete change of heart. Frankly acknowledging himself beaten, he said, "I am going home to learn."

The Centennial is an old story, but it taught us many valuable lessons. What could be more suggestive to the thoughtful man than the general display made by Great Britain and her Colonies? Those who recall this exhibit will remember how, on coming from the western entrance of the Main Building, we first came in contact with the raw materials from the Colonies, and that Australia was conspicuous by its exhibit of a monolith showing in bulk the extent of its gold product. Every step forward was the putting behind of these raw materials and meeting a higher degree of thought and skill; until in the grand transept, in the exhibits of the Doultons and the Mintons, we found the very soil of England transformed by skilled labor, and bearing values far greater than that of the gold of Australia; while in the Elkington exhibit gold and silver themselves became raw materials on which to float thought expressed by skilled labor more valuable still.

At this Exhibition we were forced to recognize the industrial superiority of France as well. I am told that the poorest grades of cotton in the French exhibit surpassed the very finest cotton products which we had to show. It may be said that the development of our textile industries has only just begun.

Acknowledging, then, the general inferiority of our industrial development, as we must, save in a few directions, and acknowledging also the importance of industrial power to any great nation, the question arises, How can our industrial manufactures be promoted? I answer, *By the promotion of that factor which is the main element of value in them, human thought expressed by skilled labor.*

The nature of the thought required, and the manner of expressing it, are indicated by the industrial articles which we have been examining. Take this caliper, for instance. As we have seen, but a few

cents' worth of iron ore is here carrying a value, created by thought, four hundred fold beyond the value of the material. Now, in order to render the raw material—iron ore—suitable for this ultimate purpose, thought has played all about it, has brought great natural forces to bear upon its constituent atoms, and has recombined its inherent forces in a manner suitable to sustain the idea that thought has desired to impress into and upon it. Again, in the case of this vase, thought has been, as it were, playing about the raw material of common clay, readjusting its constituent elements to serve an industrial purpose, and the material, when thus reconstructed, has become the basis, as it were, upon which thought has expended itself in a purely æsthetic direction, creating great value by ministering to æsthetic tastes. Again, in this copper vessel we have thought working through skill; and, without changing at all the constituent elements of the material, it has created a new value by impressing thought upon the metal by the skillful work of the hand.

Thus we see that thought, to create these wide-spread industrial values, needs to be enriched by science, which shall inform it with regard to the constituent elements of the materials it has to deal with, and the nature of the chemical and physical forces which may be brought to bear upon them; and also by æsthetic art, that it may make use of the principles which govern the production of beauty. Furthermore, it requires the aid of graphic art, as a definite language in which to express its conceptions, and a knowledge of the manual arts, that there may be sufficient skill of hand to embody in the desired materials the thought expressed by graphic art.

Such is an outline of what is necessary for the development, enrichment and application of thought for industrial purposes. To elaborate the details of each subject is impossible within the present limits, and only the general features of each can be referred to here. Grouping them under the three heads of Science, Art, and the Manual Arts, the fundamental elements in each subject may be outlined and illustrated as follows:

First. In Science, a knowledge derived from practical observations of the laws and phenomena of chemical and physical science, such as light, heat, electricity, magnetism, mechanics, molecular motion, chemical affinities, quantitative and qualitative analysis, etc., etc.

These are some of the more fundamental features, and need not be more than referred to here.

Second. In Art, a knowledge of the features of graphic and æsthetic art, which are three fold in their nature and relate to

1. Construction, or how industrial objects are made.
2. Representation, or how objects appear.
3. Decoration, or the enrichment of articles by ornament for the purpose of increasing their value.*

Third. In the Manual arts a knowledge of the fundamental manipulative processes in dealing with raw materials. The worker in iron for example, must be familiar with the processes of bending, drawing out, welding, punching, etc.; and in wood work a knowledge of planing, cutting and splitting, sawing, joining, turning, etc., is essential. In steel work we have the following, among various manipulations: Filing to line; sawing and filing; free-hand filing; fitting; chipping, etc.

There are various industries whose manipulative processes might be educationally arranged in a similar way.

Having thus seen that in industrial products the most important and most valuable factor is human thought, having seen further that for the practical development of this thought it needs to be enriched by a knowledge of Science and Art, and equipped with a knowledge of the Manual arts, our next inquiry is, How can these results be secured?

Before answering the question directly—and especially as by our statistics we have brought the commerce of England and France into contrast with our own—let us turn our attention for a moment to what England and France, our two most powerful industrial and commercial competitors, are doing in the way of protecting their commerce by protecting and stimulating their industries.

A brief survey of their efforts in this direction will show us that to an extent far beyond what is comprehended in this country they are utilizing the forces of public education as tributary to this end. Our statistics show us that England is leading the whole world in commerce, and this through the industrial development which is carrying her commerce along with it. If we look carefully into the imperial

* These features were illustrated by a number of charts and drawings, showing how drawing is practically applied in industry.

The work in iron, wood, and steel was illustrated by examples of shop work from the Institute of Technology, Boston. The teaching of special or complete trades in this elementary construction was discountenanced.

policy of Great Britain, we shall find that this result is no mere accident, neither is it wholly the result of fortuitous circumstances.

It is a result which has been deliberately planned. For more than thirty years England has been spending immense sums of money for the avowed purpose of developing her industries through increased skill and taste. So systematic have been her efforts, so munificent her expenditures, that she has established industrial museums and schools of science and art by the side of every important industry in the kingdom, and has expended over $20,000,000 in supporting them; and she is now supplementing these efforts by still broader provisions for the industrial education of her artisans in her national schools.

It is generally conceded that it is to these efforts that England mainly owes her present industrial supremacy.

If we turn to France, we find similar efforts in progress. In many respects the higher branches of technical education are better systematized and better developed in France than in England. At the same time, the trade education in France—that is, the training in the trades themselves—is broader than in England.

The recent efforts of England, however, through her national schools, will soon place her still further in advance. It may be said in this connection that France is endeavoring to meet England on her own ground, as will be seen by an examination of the recent provisions for public education in France.

If we were to extend our observations to Germany and Austria, we should find in those countries, also, the evidences of an earnest industrial arming. Indeed, Austria, a State which thirty years ago was behind nearly all Europe in education, is now looking to the development of industrial education with a liberality and a degree of practical foresight which challenge our most serious consideration.

To measure the exact effect in dollars and cents of such educational investments is, of course, impossible; yet it is the concurrent testimony of all who have given attention to the subject, that by such means only can industry be promoted in any broad way, while the results which have flowed from the efforts which have been undertaken, particularly in England and France, have been simply incalculable. If time permitted a study of the details of English and French commerce for the past few years it would be full of interest in this connection.

These facts show us that for industrial development—for the pro-

motion of thought in industry—public education is a most powerful weapon, and our commercial statistics tell us only too plainly that we in this country, with the most opulent material resources, and with a most intelligent and enterprising people, have hardly begun a course of industrial development.

For the purpose of substantiating the statement made in the beginning of these remarks, permit me to turn aside for a moment from the main argument, to bring this matter directly home to you here in Philadelphia.

I am assured that the annual product of your local manufactures is about $500,000,000. If this be so, you have an immense interest at stake in this question, and if what I gather from some of your leading manufacturers be true, your industries are far from having reached their maximum development in the matters of skill and taste. This being true, the assistance they need, the *vital protection* they need, is to have more thought in them—a higher degree of skill and taste among the artisans engaged in them. By providing this thought and this skill they will be most securely protected, and I do not think it too much to say, with the results of European experience before us, that the expenditure of $1,000,000 annually for broad industrial education would soon return you an increase of ten times that sum, in the enhanced value of your products, without additional cost for material, and with a reduction of cost in many directions. With such facts before you, with your vast industrial interests at stake, with the great activity of your industrial competitors on the other side of the water, aiming their industrial forces directly at your workshops, deem me not impertinent if I ask, What are you doing in the way of practically protecting your most important interests? Where are your schools of Science and Art, and your Industrial schools for artisans, such as you find at Birmingham, Sheffield, Leeds, Kommatow, Mulhouse, Creusot, Zurich; or your Industrial museums like those at London, Paris and Vienna?

This is a question for you to answer for yourselves. Without going into further details, you will agree with me, from what has been shown, that not only does your future industrial prosperity depend upon your securing more thought as expressed by skill and taste in your industries, but also that one of the most important matters which can engage the serious intention of your community and Board of Trade is this question of practical industrial education.

Turning now to the broader, or to the national aspect of the subject, the question arises, how can the education which we have seen to be so valuable, and which is being so earnestly promoted abroad, be introduced in this country?

I answer, it can be introduced in this country better and far more effectually than in any other country. We have simply to avail ourselves of our already established system of public education. By a readjustment of some of its features, and an incorporation therein of certain others, the main object can be accomplished. In this matter I know there are some difficulties in the way, and many prejudices to be overcome; still the thing can be done, and nothing is surer than the fact that the public schools will ultimately be made to answer to broad public needs in this respect.

In engrafting industrial education upon our public education we shall have a great advantage over our foreign competitors in this respect. Our general system of public instruction has already been organized. With all its drawbacks, it is free from many of the bones of contention which surround public education abroad. On the other hand, in promoting industrial development, the public schools will be advancing their own interests. They have of late received the fiercest criticism from many quarters, and the burden of this criticism seems to be that our public instruction is wanting in practical elements. But I cannot state this aspect of the case more strongly than it was stated in an address before the Franklin Institute in 1874, by one of its most honored members, Mr. Coleman Sellers, who summed up his argument by saying, "Our common school education gives us traders, gives us shopkeepers, but it gives us no artisans. I know not if this can be remedied, but I do know we require some other training for our sons and our daughters."

This feeling is so universal a one, and is so closely related to the subject in hand, that I trust you will pardon me for stopping a moment to show, in a graphic way, why it is that our public education is so practically out of joint.

In all education what is it that we educate? Where do we lodge the instruction? What particular organs, senses, faculties, do we develop? The effort is to develop thought. What is thought, and how is it generated? Thought is brain power. Thought in literature, commerce or industry is produced by the legitimate physical action of the brain, and to study the purely materialistic action of the brain

in generating and expressing thought becomes a primary consideration in all education.

Studying the functions of the brain, we find that for educational purposes it may be likened to an organism with a threefold form of working, an organism with a power of absorption, a power of assimilation and recreation, and a power of expressing or giving out. The force or character of a brain is measured entirely by its expressing power, by what comes out of it. Examining a little closer, we find that the brain absorbs through all the five senses, while for expressing purposes it makes use of but two of these senses, or rather of but two organs of these senses—the tongue and the hand. Fig. 1 is a simple

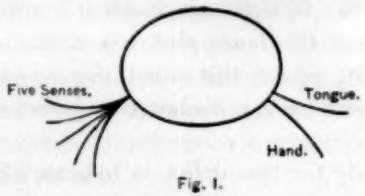


Fig. 1.

diagram representing a brain with the five senses placed on one side, as means of absorbing power, while on the other side the tongue and the hand are placed as organs of expressing power. The other function of the brain, that of assimilation and recreation, cannot of course be graphically represented. It may, however, be said to be the result of the action of the other two functions. Now the equipping of a brain, or the healthy education of a brain, consists in giving it expressing power through the tongue and the hand, coextensive with the power of absorption and the power of recreation.

Applying our popular schemes of education to the brain, and especially those based on the 3-R idea of education, we find what is indicated in Fig. 2, that provision has been made for greatly distending

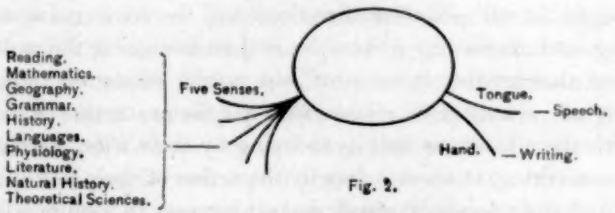


Fig. 2.

the absorbing side of the brain, while for the expressing side, the practical side, provision has been limited to the use of the tongue in

speech and to the hand in writing. If now we follow the result of this brain equipment into practical life, we find that speech and writing as means for expressing thought have their applications mainly in the commercial and financial employments and the professions, and only incidentally in the industrial and mechanical employments. With such an inadequate and one-sided brain equipment, it is not possible in any broad, practical way to bring thought or brain power to the service of industry. The fact so generally admitted that we are getting so few intelligent artisans or mechanics from our scheme of public education, that we turn out pupils of both sexes with a decided repugnance to industrial labor, is an attestation to the truth of this statement. The simple fact is, that our education is not broad enough on the expressing side of the brain, that too much attention has been given to the absorbing side of this organ, that no adequate provisions have been made whereby it can discharge its power in work connected with the industries.

In Fig. 3 a remedy for this defect is indicated in the addition of

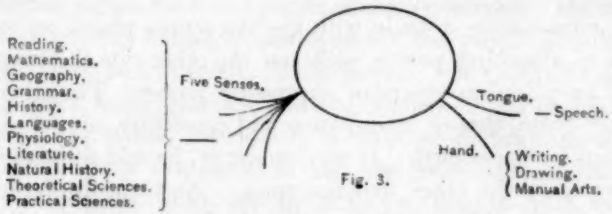


Fig. 3.

the study of graphic and æsthetic art, through drawing, and of training in the manual arts, to the previous brain equipment. Observe where these features come in the scheme—on the expressing side of the brain and in the service of the hand, thus giving the brain ample power to discharge thought in its most complete form for use or for beauty. With these features added to the brain equipment its power of expressing thought in all practical directions will be coextensive with its absorbing and recreating powers; and just as soon as the public can clearly see that in the outcome of our public education there is no respecting of persons or of classes, that pupils are trained for honest labor with their hands as well as to living by their wits, are taught to produce something, to *create values* by the action of their brain through the work of their hands, a much deeper interest in public education will not only be manifested, but generous provisions for its support will also be given.

The practical solution of the problem we have been considering is not a difficult matter. It consists of providing better instruction in Science and in Art, and in making provisions for the instruction of our youth in some of the Manual arts.

All that is necessary in the instruction in Science and in Art is to reform the teaching in both subjects, and to make it more practical. Bring Science down from the High School to the Primary and Grammar Schools: teach it not by theory, nor even by the ordinary object lesson, but give pupils an opportunity to work with materials, to make experiments, and thus to observe the results which take place under their own fingers, thereby gaining knowledge as well as manipulative confidence and skill. All this is possible.

In teaching Art a radical reform should be instituted. Substitute for the dilettante drawing which cumbers many of our schools, systematized and practical work like that which we have been considering, and which finds practical applications in education in our industries and in true æsthetic culture.

In regard to training in the Manual arts, the question being one of comparatively recent growth presents more serious difficulty. The principal lines of work have been suggested and illustrated already; but that which has been accomplished in this direction has been done mainly in special mechanical schools like those of the Boston Institute of Technology, or of the Washington University at St. Louis, and a few other technical schools. The present problem is to bridge over the ground between the industrial training of the Kindergarten and that of these technical schools.

I think, however, that a full consideration of the question will show no insurmountable obstacle in the way of attaching like training schools to our public school system, or in the way of ultimately incorporating instruction in some of the fundamental manipulations in the Manual arts into a regular scheme of public instruction. Various efforts are being made to solve this problem, and with the general interest in the subject which now exists, I have no doubt but that the demands of practical public education will make themselves felt in this direction.

If my argument, then, be a sound one, we see that the material prosperity of this people, and especially of this community, is coming to depend to a very great extent upon the development among all classes of a knowledge of industrial science, art, and manual skill; that the promotion of this knowledge is fundamental to any broad material

development, and that as yet but very meagre provisions have been made for it.

We see also that the most efficient provisions which can be made for this education must be made in connection with the public schools; and that in order to give proper elementary industrial training in our schools, we must have more practical and universal teaching in Science, and more carefully systematized, more definite and broader instruction in industrial art; and that training schools in the Manual arts should be grafted upon our present system of school instruction.

These ideas are not new; many of them have been carried into practical effect, as we have seen from our illustrations; but although the subject is not a new one, it is one whose educational, whose commercial, whose political importance is now for the first time gaining recognition. The more careful the study given to this question, the more vital does the necessity for this development of industrial thought appear, and I do not feel as if I could emphasize too strongly the imperative necessity to our political and commercial prosperity of a judicious investment in this tremendous, this incalculable source of wealth, the development of the industrial thought of the nation.

A serious word just here. We hear much in these days about protection to American industry. If my presentation be a true one, we are to-day sadly unprotected against the industrial competition that is coming against us from Europe, a competition against which no tariff can alone protect us. Remember that it is not now the pauper labor, but the skilled labor of Europe with which we have to contend. Europe has been arming for this contest for years, and is now putting millions of skilled workmen into her workshops. Against such a competition no tariff can give adequate protection, and if I may be permitted to do so, I would suggest as a fundamental article in the creed of protection, *The industrial education of the American workman.*

One word more in explanation. I am aware that in stating the question thus broadly and practically, I lay myself open to the charge of advocating a materialistic education. Such, however, is not at all the result which I believe will follow. In a government like ours the development of good citizenship must always hold a foremost place in all schemes of education.

What is the basis of good citizenship?

It rests, in individual cases, primarily on the power of maintaining

oneself in the struggle for existence; and when you observe the complex conditions under which life is given to us to-day, when you consider the necessity which rests upon every mechanic and artisan of Philadelphia that he shall produce something by the action of his brain and hand, something which shall exchange with the food produced by the Illinois farmer on the one hand, and with the work of artisans or producers in other communities on the other, you see that the first condition for good citizenship on the part of your industrial producers here in Philadelphia is the possession of the power of supporting themselves by selling the expressions of their thoughts in iron or wood or steel or textiles. If it be not too abstract a thought, it may be said in this connection that the degree in which man becomes a good citizen, and the degree in which he becomes interested in the whole scheme of social and political order, can be approximately measured by the means afforded him for the creation of wealth and for the exchange of his products.

It may be alleged that I put even a material value upon citizenship. In one sense, I do. The material value of social and political order should, it seems to me, be the starting point for the consideration of the subject, for, with all due respect to theoretic sentiment, in these days when the rapid increase and aggregation of population in industrial and commercial centres are presenting new problems in social, political and economic science, the responsibilities of life are too real and too fearful to admit of our relying wholly upon theories of human conduct, however sacred or however venerable. Strikes among miners and trade-union operatives are the legitimate, wasteful and barbarous attendants of our present industrial development. These evils are not to be corrected by the establishment of Sunday schools or by the distribution of religious tracts. We have first to deal with the people engaged in the industrial employments as men, having like interests, hopes and fears with ourselves. We must give those who live by the industries a fair chance; we must afford the men who are engaged in industrial labor an opportunity to live as men, and not as unthinking machines, or as ignorant beasts; and the first great step towards the reconciliation of labor and capital seems to me to be this,—industrial education.

No, it would be an entirely false conclusion to say that the idea of education we have been considering tends to merely materialistic ends. It is true that its first object is to reach a material result through the

concretion of human thought, either for use or for beauty. In the process, however, the very foundations of human knowledge, we may say of human culture, are laid hold of. The mind of man is pressed by an inexorable necessity against the primal forces of nature, feeling "God's great hand in that darkness;" and in studying the constituent action of these forces, in learning to appreciate their infinite extent, their marvelous power, he is brought into direct contact with eternal things. Whether dealing with iron, or textiles, or precious metals, he comes at last to see that these very materials in their last resolution are but emanations of that supreme power, which, clothed though it may be in the phraseology of the "Persistence of force," or invested with the personality of Zeus or Jehovah, pervades all things.

Industrial education therefore, properly comprehended, means not simply the training for a trade, but the building up of a good citizen, who contributes by his thought, expressed by skilled labor, to the happiness of mankind. Trade and commerce are but servants to such a citizen, and by exchanging his products, they link him indissolubly to the preservation of social and political order, as mere accessories to the full development of his own spiritual individuality.

And this is industrial education from a business standpoint.

Variations of the Hydrogen Lines.—Rutherfurd first established a classification of stars according to the nature of their spectra by pointing out the differences in the hydrogen lines in different stars. Secchi confirmed his observations and showed that the solar lines, especially those of sodium, magnesium and hydrogen, vary in breadth and intensity in the neighborhood of Sun spots. The late beautiful researches of Huggins have also shown variations, in the violet and ultra-violet portions of the spectrum, which can only be studied by the help of photographic processes. Fievez finds, by experiment, that the breadth of the lines varies in proportion to the elevation of temperature, and that very slight traces of one or more elements can be detected by a sufficient elevation of temperature. In this way he finds that the C and F lines of hydrogen are each bordered by two fine lines, which form a triplet with the principal lines. He regards his observations as interesting, in view of the study of the harmonic or rhythmic structure of spectral lines, which has been pointed out in this Journal (vol. civ, p. 288, etc.)—*Bull de l'Acad. de Belg.* C.

Fluctuations of Sulphur Springs.—M. Villot has studied the variations in the flow and strength of the sulphur springs at Camoins-les-Bains. The waters are cold, and their sulphur appears to come from the decomposition of gypsum by the organic matters with which the surface waters become charged while circulating upon the surface or in the sub-soil. They contain free sulphuretted hydrogen, together with sulphuret and sulphate of lime in solution. Irrigations by artificial canals injure the spring, sometimes diminishing the strength of the waters more than two-thirds when the bathing season is at its height.—*Ann. des Mines.* C.

Cotton in Italy.—The American war stimulated the cultivation of cotton in Italy, and excited great expectations of permanent prosperity. The continual and sudden diminutions of temperature, during the season when the bolls are ripening, proved a great obstacle to the cultivation in the southern provinces, and it is now confined almost entirely to limited districts in Sicily and the lower peninsula. The factories and private looms for weaving textile fabrics suffer greatly from competition with the importations from other countries, and the question of a protective tariff is awakening much interest. Fedele Borghi, referring to the early history of cotton manufacturing in the United States and to its subsequent marvelous growth, believes that a similar protective policy would lead to similar results in Italy.—*Il Politecnico.* C.

Modification of the Ruhmkorff Coil. — G. Scarpa and L. Baldo constructed a Ruhmkorff coil with a helix divided into three movable compartments. Under the ordinary arrangement the sparks produced by three Bunsen cells had a length of 6 centimetres (2·36 in.); when the middle compartment was removed without disturbing the others the length of the spark was perceptibly increased; when the thread of the middle compartment was wound around that of the other compartments they obtained a spark of 8 centimetres (3·15 in.) They then wound the wire so that the current would pass from the exterior extremity of one of the superficial coils to the corresponding central coil, and then continued through the other coil to the exterior extremity of the second superficial coil. With this arrangement they obtained a zig-zag spark of 13 centimetres (5·12 in.), of exceeding brilliancy.—*Revista Scientif. Indust.* C.

Lunar Observations in Algiers.—M. Faye has communicated to the French Academy the first series of lunar observations which were made at the new observatory at Algiers by its director, M. Trépied. These observations strikingly confirm the accuracy and importance of Newcomb's corrections of Hansen's tables. M. Faye anticipates from a continuation of the observations further valuable results, which will amply justify the establishment of the new observatory.—*Comptes Rendus.* C.

Electricity of Mechanical Vibrations.—Mousson, in 1858, found that the conductibility of metallic wires is affected by vibrations. Dr. de Marchi has recently resumed the investigation. He finds that every stretching of a metallic wire generally increases its resistance; the increase is commonly proportional to the increase of stretching, but after reaching a certain limit the variations proceed by jerks, showing a momentary and profound disturbance of the molecular state of the wire.—*Revist. Scientif. Indust.*

[Chase showed in 1864 that the variations of the magnetic needle could be explained by the mechanical action of the convection currents of the atmosphere.] C.

Relation of Magnetism to Atomic Weight.—Leo Errera deposited with the Royal Academy of Belgium, in January, 1878, a sealed note upon the "law of magnetic properties," which has lately been published on account of Carnelly's having arrived at conclusions identical with his own. He concludes that the bodies of the uneven series, in Mendelejeff's groupings, are diamagnetic; the bodies of even series are paramagnetic. He proposes to show, in subsequent communications, that the periodicity exists not only in the fact of paramagnetism or diamagnetism, but also in the intensity of those forces. He is now endeavoring to establish a like periodicity for many other physical properties, especially for the points of fusion and volatilization. He predicts that vanadium will be found decidedly paramagnetic; lithium, rubidium, zirconium, rutherium, cœsium, thorium, and perhaps ytrium and erbium, will be slightly so. As to calcium, strontium and barium, contrary to the opinion of Faraday, they will also probably be attracted, at least slightly, by a very powerful magnet. On the other hand, thallium, gallium, and probably indium, will be diamagnetic.—*Bull. de l'Acad. de Belg.* C.

Curious Physical Phenomenon.—Dr. Grassi used three concentric vessels with an annular space of about 2 centimetres (·787 in.) between the first and second and between the second and third. The outer space was filled with oil and the next with water. The oil was heated by a furnace to a little over 100° (212°F.), and the water boiled. Then hot oil, *e. g.*, 150° (302°F.) was poured into the central space. This quickly cooled to a temperature about equivalent to that of boiling water. The oil cooled more rapidly the higher the temperature of the outer oil. Dr. Grassi referred to an analogous phenomenon, discovered by some members of the Academia del Cimento, who found that the water in a vessel surrounded by ice cools more rapidly when the ice is heated in order to accelerate fusion.—*Proc. Roy. Inst. Lomb.* C.

Prevention of Locomotive Sparks.—Albert Focke proposes the following arrangement for preventing the escape of sparks from the chimneys of locomotives. A conical tube is fixed centrally within the chimney, with its large end extending down just into the blast pipe and its small end reaching about half way up the chimney. Above this conical tube is fixed another and shorter tube, in the form of an inverted truncated cone, above the mouth of which there is a metal disc. Part of the exhaust steam which issues from the blast pipe passes up through the lower conical tube into the upper one, and is deflected by the disc, outwards and downwards, into the annular space between the tube and chimney. Sparks that are carried up the annular space by the exhaust steam from the blast pipe are met by the counter current and are thereby extinguished.—*L'Ingen. Unir.* C.

New Electric Property of Selenium.—Blondlot attaches to one of the poles of a capillary electrometer, by means of a platinum wire, a fragment of annealed selenium; to the other a plate of platinum. If the selenium is brought in contact with the platinum, by an insulating rod, the electrometer remains at zero; but if the selenium is rubbed against the surface of the metal the electrometer is immediately powerfully agitated. A deviation may thus easily be obtained, equivalent to that which would be produced by a cell of sulphate of copper. Neither the friction of two metals against each other, nor that of two insulators, can produce any charge. The selenium current flows through the electrometer from the unrubbed to the rubbed selenium, consequently the disengagement of electricity cannot be attributed to the heat which accompanies the friction.—*Compt. Rend.* C.

Book Notices.

THE CIVIL ENGINEER'S POCKET-BOOK. By John C. Trautwine. Fifteenth thousand. 1881.

The question has frequently been asked, "What becomes of all the pins?" It might almost as well be asked in reference to this well-known and useful work—one which might be supposed to be used by the comparatively few only, but which, from the extensive demand for it, must be much more widely used by other technical men than civil engineers, for whom it was originally designed. The present edition—the second one this year—has been carefully revised and enlarged, errors of earlier editions, typographical and otherwise, corrected as far as noticed, although a few comparatively unimportant ones still remain.

Among the articles added that on "Centres for Arches" will be found a very useful and instructive one for engineers particularly the large number who have not had the practical experience of the veteran author, giving as it does examples of defective construction and modes of striking centres to be avoided, as well as examples of successful construction and proportions desirable to be followed.

In glancing over the tables, in that on page 416, "Table of Radii, Middle Ordinates, etc., of Curves," and incidentally comparing them with some calculations of our own, in the small angles below 10 minutes, we find some discrepancies. As these angles are hardly ever used, a correction would be needed only for strict accuracy; above 10 minutes there is no material difference as far as noticed.

As we learn that those in this work were computed from Hutton's tables of *natural* sines to seven places of decimals, while ours were found by using Young's *logarithmic* tables (carefully compared with those of Callet, Vega, etc.) to the same number of places of decimals, the discrepancies must have arisen from the use of the different tables from which the computations were made, so the question arises, which to use, natural or logarithmic tables for small angles? We prefer logarithms, as will be seen by the following.

Our author has used the following rule: Subtract angle of deflection from 180°, then say as natural sine of angle of deflection is to natural

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sine of *half* the remainder so is the given *chord* to the radius required.

Example.—Let the angle of deflection be 0° 01′, chord 100 feet (as usual in the table), required the radius.

$$\overline{180° - 0° 01'} \div 2 = 89° 59' 30''$$

Then, as $\begin{matrix}\text{nat. sine } 0° 01' \\ \cdot 0002909\end{matrix}$: nat. sine, $\begin{matrix}89° \\ 1\end{matrix}$ 59′ 30″ : : $\begin{matrix}\text{chord} \\ 100\end{matrix}$: $\begin{matrix}\text{radius} \\ 343760{\cdot}74\end{matrix}$

Our practice is to use logarithms according to the following formula: As the chord of the arc is 100 feet, in setting out stations on a curve the sine will be one-half that = 50 feet, and as the angle of deflection D is one-half the angle at the centre, known as the "degree of curve," we will have $\therefore R = \frac{50}{\text{sine } D}$.

Example by *logarithms* for 0° 01′ curve:

2) 0° 01′		10·
0° 00′ 30″	Log. Sine.	6·1626961
	Ar. Co.	3·8373039
50 feet.	Log.	1·6989700
343774·64 feet Radius		5·5362739

As the angle increases, the results by the two methods approach more closely until at 0° 10′ they nearly correspond.

As somewhat similar discrepancies were also noticed in some pocket table books by other authors, the following will be found useful for correction and comparison.

Angle of deflection.	By natural sines. Trautwine. Radii.	By logarithms. C. H. R. Radii.
0° 1′	343761	343774·64
2′	171880	171887·39
3′	114587	114591·55
4′	85940	85942·63
5′	68752	68754·93
6′	57293	57295·78
7′	49109	49110·68
8′	42970	42971·84
9′	38197	38197·19
10′	34378	34377·47
15′	22918	22918·33
6° 0′	955·4	955·366